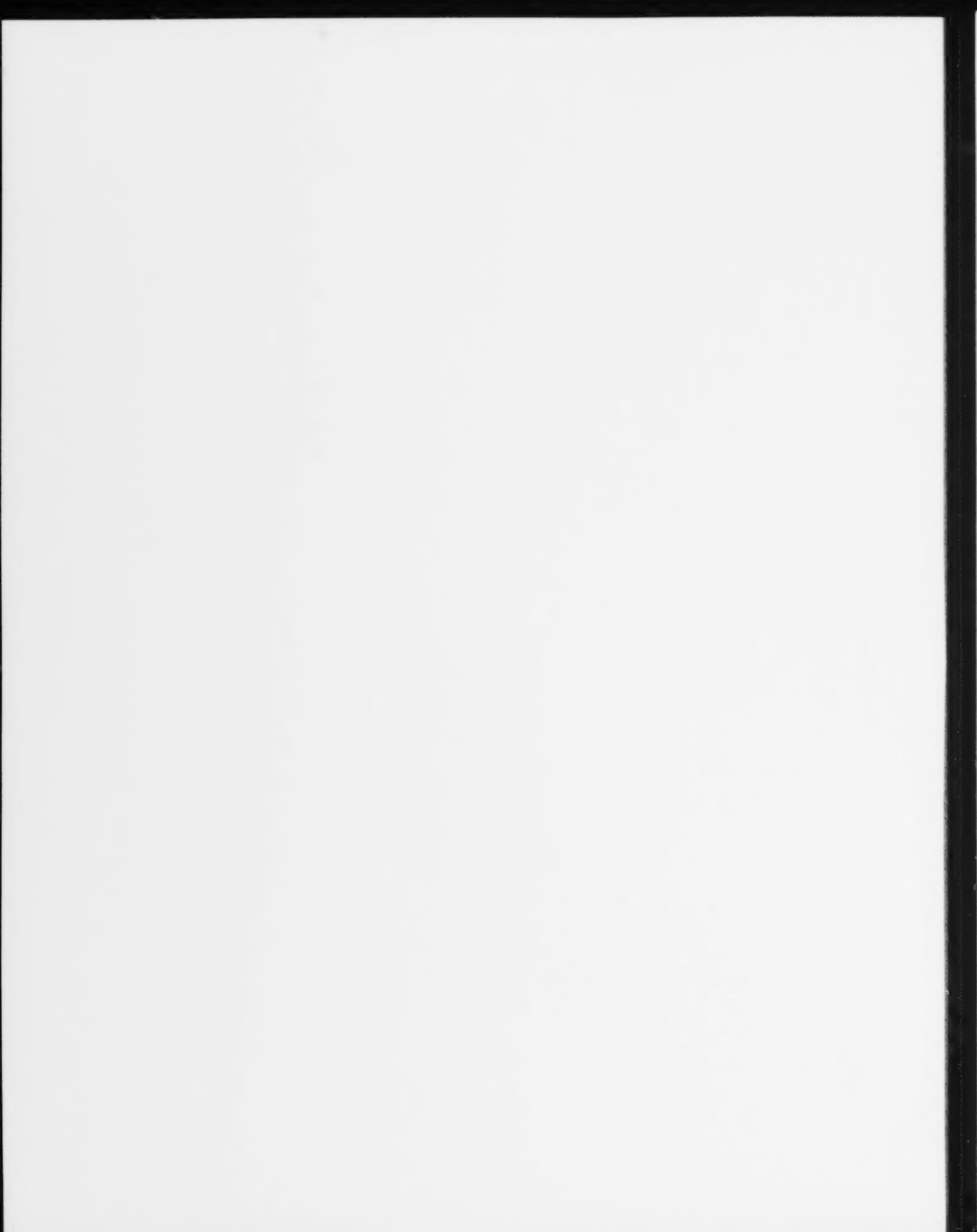

**Lillooet
Forest District**

**Documentation of
Vegetation Resources Inventory
Preliminary Analysis**

**PREPARED BY:
MINISTRY OF FORESTS
RESOURCES INVENTORY BRANCH**

October 23, 2000



Lillooet Vegetation Resources Inventory Analysis Report

Acknowledgements

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Executive Summary

This report documents the Vegetation Resources Inventory (VRI) preliminary analysis that was completed for the Lillooet TSA in anticipation of the Timber Supply Review (TSR) II in 2000. The report was developed in conjunction with Ministry of Forests staff from Resources Inventory Branch, Timber Supply Branch, the Kamloops Region, and the Lillooet Forest District.

The report references and contains content from the previously developed "VRI Lillooet Forest District Inventory Plan", dated January 30, 1998.

This analysis focussed on the development of adjustment factors for height, age and volume to support the current timber supply analysis. The process used to derive these adjustments is interim and may change in the future.

The results of the VRI analysis indicate that volumes in the vegetated, treed landbase are under estimated by 17%¹. Further post-stratification of the results suggest that volumes for the operable landbase are generally accurate, while volumes in the inoperable land base are underestimated by about 44%². These results are compiled using a utilization level net of decay, waste and breakage and do not include any new taper and decay results. Net Volume Adjustment Factor (NVAF) sampling in the Lillooet Inventory unit has been started but is not yet complete.

Approximately 23 additional ground samples will be established in the 2000 field season. This analysis does not incorporate data from these samples. Stakeholders will review the analysis during the fall of 2000 to determine if further sampling is required.

¹ The ratio of the VRI volume to the unadjusted inventory volume in the vegetated, treed landbase (n=128) was $1.17 \pm 14\%$, where the sampling error is calculated for a 95% probability level.

² The ratio of the VRI volume to the unadjusted inventory volume in the operable (timber harvesting landbase) was $0.99 \pm 16\%$ (n=71). For the inoperable (non-timber harvesting landbase) the ratio was $1.44 \pm 22\%$ (n=37). Sampling errors reported here are for a 95% probability level.

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1 Introduction

1.1 Purpose

This report was assembled to provide a detailed description of the procedures and assumptions that went into the preliminary analysis of the Lillooet TSA Vegetation Resources Inventory data and to document the results to date.

The primary purpose of this report is for documentation. Stakeholders in the Lillooet TSA must review this report and determine how best to use the results contained herein.

1.2 Background

The primary driver for initiating a Vegetation Resources Inventory project in this management unit was concern regarding the accuracy of the existing inventory.

In October of 1997, a Vegetation Resources Inventory Strategic Plan (VSIP) was prepared for the Lillooet TSA. The objective of this strategic plan is to identify forest management issues and methods by which the Vegetation Resources Inventory (VRI) program can address these concerns. Forest management issues in the District included:

- the quality of work involved in the 1988 re-inventory of the District;
- increased pressure on operating landbase caused by removals and moratoriums;
- refinement of delineation of lodgepole pine types excluded from timber harvesting landbase;
- wildlife habitat area delineation;
- possible mislabelling of high elevation spruce/balsam stands;
- over-estimation of age in the current inventory;
- dry belt fir issues;
- incidence of root rot and other forest health issues (eg. pine beetle);
- criterion indicators for provincial monitoring of sustainable forest management.

The area considered in the VSIP covered the entire landbase within the administrative boundaries of the District, including TSA, private, park, and reserve land.

The VSIP outlined two primary objectives for data collection. The first objective was to implement the provincial VRI Phase II ground sampling in the Lillooet Forest District. The number of samples was calculated based on a target sampling error of $\pm 10\%$ (95% probability) for timber volume in the entire District³. It was expected that the ground samples could also be used to compute sampling errors for other VRI attributes.

³ The provincial VRI cover the vegetated treed landbase as well as the vegetated non-treed and non-vegetated portions of the landbase (areas coded as VT, VN and N in the BC Land Classification System).

The original VSIP recommended a total of 215 ground sample plots be established, 125 of which were to collect full VRI data and 90 of which were to collect timber emphasis data only. Of these, 160 sample clusters were to be established in vegetated treed areas (70 full VRI and 90 timber emphasis). The sample size of 160 in the treed portion of the District was determined to provide a 10% sampling error for net volume at the 95% level of probability.

After subsequent review, the stakeholders decided not to do a full VRI. Instead, it was decided to focus the ground sampling on the vegetated treed portion of the landbase. Two further objectives were defined:

1. To achieve a target sampling error of $\pm 10\%$ (95% probability) for timber volume in the vegetated treed portion of the landbase in the Lillooet District
2. To achieve a target sampling error of $\pm 10\%$ (95% probability) for timber volume in the vegetated treed portion of the *operable*⁴ landbase in the Lillooet District.

To address the second inventory objective of improving the accuracy of the timber volume inventory in the timber harvesting landbase, one sub-unit was created within the Lillooet Forest District. The sub-unit population of interest was defined as the treed portion of the Lillooet TSA. The original VSIP recommended an additional 110 timber emphasis plots be established in this sub-unit⁵. Approximately 80% of these samples were to be located in the operable landbase.

In the 1998 field season, 70 timber emphasis plots were established in the vegetated treed portion of the district. After the first year of sampling, the sample size requirements were reassessed. It was determined that 58 additional samples would be required to meet the target 10% sampling error in the vegetated treed portion of the landbase. It was assumed that sample size would also satisfy the sampling error for the operable portion of the landbase.

To date, 128 timber emphasis samples have been established in the vegetated portion of the district. Seventy were completed in 1998 and 58 were completed in 1999. Of these 128 samples, 71 (or 55%) have been identified as operable based on the District's definition of the timber harvesting landbase.

Other ground sampling activities to support the VRI process included: Net Volume Adjustment Factor (NVAF) sampling and Within Polygon Variation (WPV) sampling.

The objective of Net Volume Adjustment Factor (NVAF) sampling was to improve estimates of tree net volume from the net factoring process. This is accomplished using stem analysis to provide local estimates of decay and tree taper. The data from stem analyses are used to develop a factor (NVAF) to adjust the net volume from the Phase II ground sampling (derived from the net factoring process and taper equations). The basis

⁴ The term "operable" is used synonymously with "timber harvesting landbase" in this document. Operability for each sample was determined using timber supply criteria.

⁵ Assuming that the Provincial VRI would take place first, 90 timber emphasis plots would have been established. With an additional 110 plots, a total of 200 timber emphasis plots would be available in the inventory sub-unit.

for the method used to calculate the NVAF, is the estimation of the actual net volume of felled trees. The NVAF sampling unit is the tree. The attributes of interest are net merchantable volume per tree⁶ and actual sound wood volume⁷. A total of 200 sample trees in at least 30 sampling points was initially recommended for sampling. However, when NVAF procedures were revised in May 1998, the target sample size changed to 50 live trees and 10 dead trees in 15 sampling points.

Within Polygon Variation (WPV) sampling is a more extensive ground sampling process than the usual VRI single-cluster per polygon ground sampling program. It measures a wider range of conditions (variability) in a polygon and produces a more accurate quantification of desired attributes for a polygon. WPV provides the variation to expect, in specific attributes, when checking timber inventory in the field and provides an estimate of the actual error of the adjusted polygon database. It also establishes a sampling protocol for measuring polygon error rates for any other resource values. WPV sampling has not yet been completed in the Lillooet TSA.

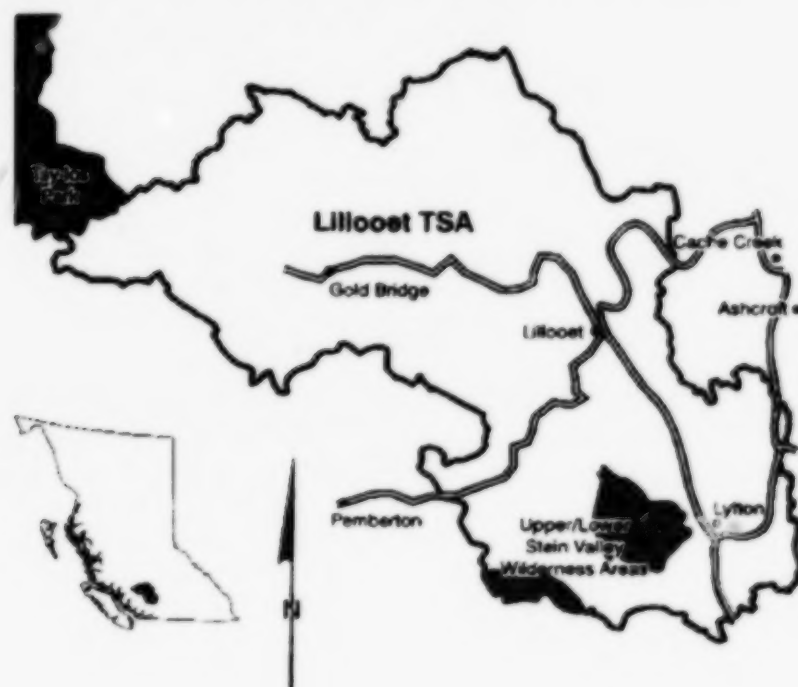
1.3 Description of the Inventory Unit

The inventory unit for the Lillooet Vegetation Resources Inventory (VRI) is the entire landbase within the administrative boundaries of the District including the TSA, private land and parks. The Lillooet TSA covers approximately 1 124 000 ha and is located on the eastern slopes of the Coast mountain range. The area encompasses drainage systems of the Stein, Yalakom, Bridge River, and portions of the Thompson River valleys, all of which drain into the Fraser River (Figure 1). The ecology of the District varies from coastal transitional to very dry interior areas.

⁶ Net merchantable volume is defined as sound wood fibre between the stump (30 cm) and the top (10 cm dib) of the tree, net of decay and waste as obtained from the VRI plot compiler (based on taper equations, net factor decision rules and cruisers' measurements).

⁷ Actual sound wood volume is obtained from volume and decay destructive sampling.

Figure 1: The Lillooet Forest District in the Kamloops Forest Region.



2 Sample selection based on original ground sampling plan

2.1 Data assembly process and database constraints

Since no new Phase I data was available for this inventory unit, the existing inventory information, ranging from 1988 to 1991, was used.

Data assembly was initiated in February of 1998 with Resources Inventory Branch staff creating the project database⁸ by collecting all Forest Inventory Program (FIP) and Forest Cover (FCI) files for the Lillooet district. Following this, all files were merged into one spatially correct, Geographic Information System (GIS) database using PAMAP software.

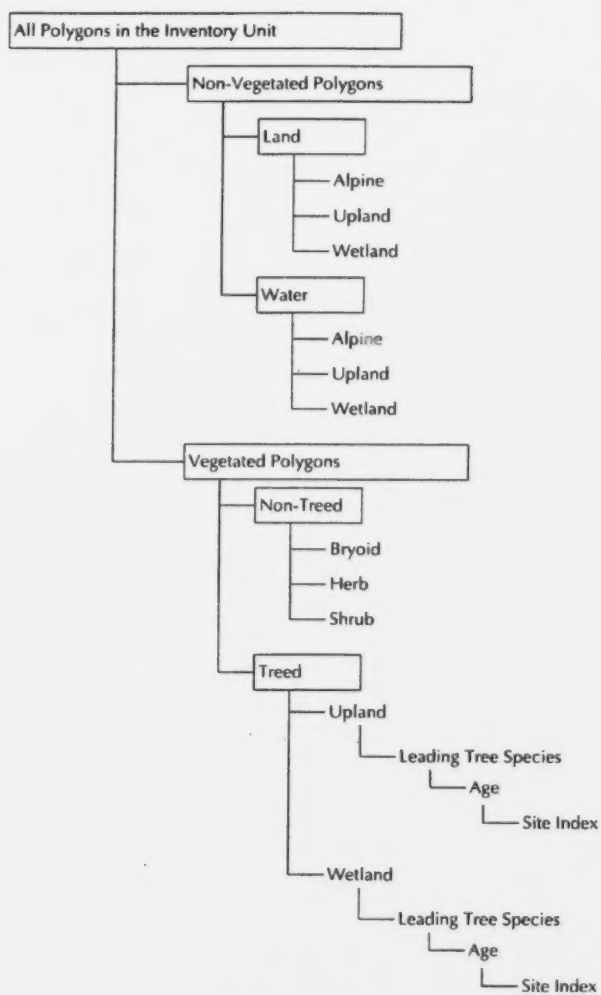
Minor database corrections were made to address split polygons. These occurred after appropriate overlays (e.g. BEC, ownership) were applied to the forest cover polygons. Where forest cover polygons were split, overlay attributes (e.g. BEC information layer) were assigned to all split polygons based on those attributes that coincided with the largest portion of the original forest cover polygon. BC Land Classification System (BCLCS) codes were also assigned to all forest cover polygons.

⁸ The Lillooet sample selection database is in a file called Lillooet_VRI&SUB.xls, residing on for059 (RIO workstation). It is also available on tape and CD from Gary Johansen.

2.2 Data sorting criteria

The objective was to sort the spatial database hierarchically by land cover classification for vegetated treed (VT) and other (i.e. non-vegetated, and vegetated non-treed), and then further within the VT classification based on leading species, projected age, and site index (re: Figure 2). This sorting corresponded with the specifications outlined in the Lillooet Forest District VRI Ground Sampling Plan.

Figure 2: Standard polygon sort criteria for Vegetation Resources Inventory ground sampling.



2.3 Sample selection procedure and sample selection issues

The original VRI ground sampling plan for the Lillooet inventory unit initially specified a total of 215 ground samples based on a coefficient of variation (CV) of 63% with a target precision for timber net volume of $\pm 10\%$ (at 95% probability). 160 samples were to be located within the vegetated, treed (VT) portion of the District and 55 samples were to be located in the remaining areas (i.e. non-vegetated, vegetated non-treed).

The sample selection process involved first systematically drawing 10,000 potential sample locations from the sorted list that included all polygons in the District. From these 10,000 potential samples, 160 were systematically drawn from the vegetated treed portion of the District. A further 55 samples were systematically drawn from other areas (i.e. non-vegetated, vegetated non-treed). Based on the operability information on the inventory files, 72% or 115 of the 160 VT samples were operable.

To accommodate the second objective for data collection, where the target sub-unit population was the treed portion of the Lillooet TSA, 40 additional samples were selected from the VT. It was assumed that all of the original 160 samples would meet both the Provincial VRI criteria and the sub-unit criteria. Hence an additional 40 samples in the inventory sub-unit would accomplish the recommended sample size of 200 identified for the sub-unit⁹.

During the 1998 field season, 70 timber emphasis plots were established. After reassessing the sample size in the fall of 1998, it was recommended that an additional 58 samples be established in the next field season. A total of 128 samples were established. All of these samples were timber emphasis and they were all located in the VT portion of the District.

3 Data Collection

3.1 Description of data collection process

Phase II ground sampling was initiated in 1998 and continued in 1999. In 1998, 70 timber emphasis plots were completed. A further 58 timber emphasis plots were established in 1999. The data collection followed standard VRI field procedures.

NVAF sampling has been completed for 48 live trees and 3 dead trees located at 10 sample sites. Details on the NVAF sampling in the Lillooet District are provided in Appendix A-1.

3.2 Contractors involved in data collection

VRI certified crews were used to collect the data following the appropriate VRI *Ground Sampling Manual*. Drake Forest Consulting carried out the ground sampling in the 1998 and 1999 field seasons.

⁹ When the 160 and the 40 samples in the VT were combined, the inventory information indicated that 148 (or 74%) of the total 200 samples were operable. This resulted in a sub-unit sample list with fewer than the targeted 80% operable samples.

3.3 Description and results of the cruise audit process (Quality Assurance): 1998-99

The quality assurance process assessed the quality of the field sampling data collection. A target measurement errors of +/- 10% for gross and net volume and +/-15% for value (when ground volumes were compared with audited ground volumes) were set for the project. This level of acceptable measurement error provides some indication for the forest manager using the data, of the possible range around the attributes (i.e., net volume or value).

9.4% of the established samples were audited by Ministry of Forests staff. There were no significant quality assurance issues identified in the audit (see Appendix A-2 for the quality assurance results).

3.4 Inaccessible samples and remedial measures taken to mitigate the effect of the missing data

In the Lillooet VRI project, there were 10 samples that were considered inaccessible due to safety or very difficult access. Using the standard VRI procedures, replacement samples were selected to match these samples. Two of the replacement samples were also inaccessible, hence a total of 12 replacement samples were required to match the initial 10 inaccessible samples.

3.5 Data entry and compilation processes

A total of 128 samples in the VT portion of the Lillooet TSA were completed and compiled for this analysis. Since this data was collected over the 1998 and 1999 field seasons, both the 1997 and the new 1999 data card formats were used.

Ground sample data was entered using the VRI data entry tool and validated in the VRI Oracle database. An ascii flat file from the database was provided for compilation in the VRI compiler.

4 Statistical adjustment of attributes

4.1 Overview

The analysis of the Lillooet VRI data used the current approach for adjustment of inventory attributes, referred to as the "Fraser Protocol"¹⁰. Note that the "Fraser Protocol" is an interim process for satisfying Timber Supply Review (TSR) needs. A more comprehensive and long-term process for adjustment of inventory attributes is under development.

In the "Fraser Protocol", the statistical adjustment of inventory attributes consists of a set of steps and assumptions used to develop and then apply adjustment factors to the FIP file attributes of height and age and the volume predicted using VDYP. The goal of the adjustment is to remove any overall bias in the inventory when compared against the VRI ground data for the attributes that are adjusted.

¹⁰ Ministry of Forests. Fraser TSA: File Adjustment Project. File adjustment recommendations. MOF ORCS 13300-20tsadjmt. April 15, 1997. 10p.

The steps in this adjustment process are outlined below:

1. Adjust height and age.
2. Based on the adjusted height and age, use VDYP to computed inventory volume.
3. Use the compiled ground volumes to then adjust this "attribute-adjusted" inventory volume.

Details of this process are described in the sections that follow.

4.2 Population for adjustment

The population for adjustment was defined as all vegetated, treed polygons¹¹ within the Lillooet Forest District. No minimum age criterion was applied. Additional populations of interest were also defined, including:

1. Vegetated treed polygons in the operable portion of the District.
2. Vegetated treed polygons in the inoperable portion of the District.
3. Vegetated treed polygons excluding those classed as "non-productive forest" (i.e., type identification = 6).

A set of adjustment factors were developed for each of these populations of interest.

Please note that all statistics provided in the body of this report are based on the population of interest defined as all vegetated treed polygons in the District (i.e., based on all 128 available samples). The adjustment factors for the other populations of interest are provided in Appendices A-3, A-4 and A-5.

4.3 Data Source

The inventory data was from the original FIP files used for sample selection, projected to 1998¹². The VRI sample number was provided on the inventory file as a link to the compiled data file¹³.

The compiled data used in the analysis was provided on March 1, 2000¹⁴. The compilation provided loss factor volumes as well as NVAF volumes. NVAF volumes were produced using a single NVAF as well as NVAFs derived from an age post-stratification.

¹¹ Coded as VT in the BC Land Classification System.

¹² The inventory data was provided by Gary Johansen on February 28, 2000 in a file called *kj_lill.dbf*. Inventory attributes for the replacement samples were provided on March 7, 2000 in a file called *replace.dbf*.

¹³ Cluster identification number on the compiled data file corresponded with VRI sample number on the inventory file.

¹⁴ The compiled ground data was provided by Alf Kivari on March 1, 2000 in files called "Lillooet cluster summary - NVAF.xls" and "Lillooet cluster x spp summary - NVAF.xls". A compilation with NVAF stratified by species and age class was provided in the files "Lillooet NVAF by spp and age class - cluster.xls" and "Lillooet NVAF by spp and age class - clsterXspp.xls".

4.4 Data issues related to the analysis

There were several samples for which no height or age data were available due to a lack of trees. In general, where the sample fell in a "hole" or untreed portion of a polygon, the ground values for height and age were recorded as "missing". However, the zero values for compiled volumes for such samples were considered as valid zeros in the analysis.

A log of data issues encountered and their treatment in this analysis is documented in Appendix A-6.

4.5 Weighting

Since there was no pre-stratification, there was no weighting required in the Lillooet TSA.

4.6 Post-stratification

The sample data used in the Lillooet VRI analysis was post-stratified in an effort to provide more precise adjustment for specific forest types within the population of interest.

The strata were determined based on a number of criteria including:

- Similar relationships in the ratios between the ground attribute values and the inventory values;
- Natural biological groupings;
- TSR analysis units;
- Number of samples available.

Using these criteria, the project team identified 4 strata, defined primarily on the leading species indicated by the inventory. The composition of these strata and the number of samples that comprised each of them is shown in Table 2 below.

Table 1: Lillooet VRI strata and sample distribution among strata.

<i>Strata composition (based on inventory attributes)</i>	<i>Number of samples</i>
Spruce, balsam, or deciduous leading	35
Lodgepole pine or whitebark pine leading	42
Dry belt Douglas-fir ¹⁵	16
Wet belt Douglas-fir ¹⁶	35
<i>Total</i>	128

¹⁵ Dry belt Douglas-fir is defined as Douglas-fir leading occurring in IDF-xh-1, IDF-xh-2, IDFdk2b, PP or BG biogeoclimatic zones and also all Py leading.

¹⁶ Wet belt Douglas-fir is defined as all Douglas-fir leading polygons not in the drybelt.

4.7 Attributes to be adjusted

4.7.1 Age and height

Adjustments for inventory age and inventory height were developed in each stratum. The adjustments used the ratio-of-means approach. The ratio for age was calculated as:

$$\text{Ratio} = \frac{\text{mean ground age}}{\text{mean inventory age}}$$

where mean ground age is the mean VRI Phase II age for the samples in a stratum and mean inventory age is the mean projected map label age for the samples in a stratum. The ratio for height was calculated in a similar manner.

A number of different ages and heights were available in the compilation of the ground data. After considerable discussion and consultation¹⁷, the following definition for ground age and height was developed:

Ground height is average height of T,L,S trees for the leading species at 17.5 cm+ utilization (from the "species within cluster" summary compilation file). If the total basal area/ha (from cluster summary compilation file) at the 17.5 cm+ utilization did not represent at least 50% of the total basal area/ha at 4cm + dbh, the utilization was relaxed (lowered) until the total basal area/ha met this criterion. If average height was not available for the leading species at this utilization, average height for the second species at this utilization was used, so long as the leading and second species were either both coniferous or both deciduous. If average height was not available for either the leading or second species, the utilization was relaxed and the leading species was reassessed. Ground age was determined in the same manner.

There were a small number of samples for which this rule provided ambiguous results. In these cases, the project team made recommendations for appropriate ground heights and /or ages on a case-by-case basis. The details of these special cases are provided in the log of data issues in Appendix A-6.

4.7.2 Volume

The adjustment for volume was developed using the same two-step process defined in the Fraser Protocol. First, the inventory age and height were adjusted for each sample polygon. These adjusted attribute values were then used as input for VDYP¹⁸ to predict an "attribute-adjusted" inventory volume. Next, ratio-of-means adjustment factors were computed in each stratum based on a ratio of the mean compiled ground volume to the mean "attribute-adjusted" inventory volume for the samples in a stratum.

¹⁷ The definition for ground age and height for adjustment purposes was developed in a series of meetings in the early fall of 1999, by RIB staff and consultants.

¹⁸ VDYP version 6.4a was used in this analysis.

All ground and the inventory volumes reported in this analysis were net decay, waste and breakage. Standard Ministry of Forests taper functions and loss factors were used in the compilation¹⁹. The ground volumes reported here were for live trees only.

Adjustment factors were developed for 12.5 cm+ dbh utilization where the leading species was lodgepole pine, whitebark pine or deciduous and 17.5 cm+ dbh utilization for all other leading species. All adjustment factors were based on volumes net of decay, waste and breakage.

4.8 Adjustment methodology

The ratio-of-means estimator was used as the methodology for adjusting the inventory attribute values. This is consistent with the approach used to adjust the inventory for TSR purposes in the Fraser TSA and the Queen Charlotte Islands TSA. The ratio-of-means methodology has also been used in other VRI analysis projects²⁰.

In general, the adjustment methodology should be unbiased and easy to apply in the TSR analysis context. Adjustment methodologies that produce non-zero intercepts must be viewed with caution since negative attribute values or (in the case of a positive intercept) minimum non-zero attribute values could have serious implications in a timber supply context.

4.9 Limitations of the adjustment methodology

Ratio-of-means is generally appropriate if the relationship between y (ground attribute, in this case) and x (inventory attribute) is linear and passes through the origin. In some strata, this was not the case and a pattern of bias was observed in the residuals (see section 7.2.3).

Alternative regression methodologies such as least squares regression and geometric mean regression typically have non-zero intercept values unless they are conditioned to go through the origin. In cases where the $y:x$ relationships do not appear to go through the origin, the regression methodologies often result in either a very shallow slope (for positive intercept values) or a very steep slope (for negative intercept values). Such functions may lead to large adjustment errors when applied to polygons outside of the range of the sample data.

Non-linear regression adjustment methodologies that go through the origin can be readily fit to the sample data. Although potential problems with non-zero intercepts can be avoided with these methodologies, the non-linear regression functions typically still face the same prediction issues for polygons beyond the highest range of the sample data as do other linear least squares regression methodologies.

Further study of the implications of alternative adjustment methodologies is required.

¹⁹ The sampling for NVAF is not yet complete. However, preliminary results using NVAF and comparisons with loss factor volumes are reported in section 6.

²⁰ Draft analyses based using ratio-of-means as the adjustment model have been prepared for the Lillooet, Dawson Creek, Sunshine Coast and Williams Lake TSAs.

4.10 Ecological and other timber attributes for which summary statistics will be generated

Ecological data was not collected in this unit. Resources Inventory Branch is currently developing methodology to summarize and report on ecological data that may be collected in the future. See Appendix A-7 for a list of reports that are currently available which summarize ecological and other timber attributes.

5 Discussion of results

5.1 Descriptive sample statistics (before adjustment)

Scatter plots showing the relationships between ground attributes and inventory attributes (age and height) are provided in Appendix A-8. The relationships between ground volume and "attribute-adjusted" volume are shown in Appendix A-9.

Mean values and confidence intervals for ground attributes and unadjusted inventory attributes are shown in Tables 2 and 3.

Table 2: Descriptive statistics for *ground* sample attributes, by strata.

Strata	Mean <i>ground</i> attributes and 95% confidence intervals			
	n ²¹	Height (m)	Age (yrs)	Volume/ha ²²
Spruce, balsam, deciduous	35	22.1 (n=31) 19.1 – 25.2	172 (n=32) 144 – 200	259 183 – 334
Lodgepole pine	42	16.5 14.5 – 18.5	119 100 – 138	156 113 – 200
Dry belt fir	16	16.7 (n=15) 13.5 – 19.9	154 (n=15) 113 – 194	77 36 – 119
Wet belt fir	35	21.1 (n=34) 19.0 – 23.2	132 (n=33) 116 – 149	168 125 – 211
Overall	128	19.2 (n=122) 18.0 – 20.5	141 (n=122) 129 – 153	178 149 – 207

²¹ Age and height were not available for all samples. The reduced sample size is indicated where values were missing.

²² Volume utilization is for live stems 12.5 cm+ dbh where the leading species was lodgepole pine, whitebark pine or deciduous and for live stems 17.5 cm+ dbh for all other leading species. All volumes are net of decay, waste and breakage (loss factors).

Table 3: Descriptive statistics for *unadjusted inventory* sample attributes, by strata.

Strata	Mean <i>unadjusted inventory</i> attributes and 95% confidence intervals			
	n	Height (m)	Age (yrs)	Volume/ha ²³
Spruce, balsam, deciduous	35	21.3 18.2 – 24.5	189 165 – 213	199 151 – 247
Lodgepole pine	42	16.3 14.7 – 17.9	129 111 – 146	143 115 – 171
Dry belt fir	16	18.1 15.5 – 20.8	193 157 – 229	82 53 – 111
Wet belt fir	35	21.6 19.7 – 23.6	167 146 – 189	149 119 – 179
Overall	128	19.4 18.1 – 20.6	164 152 – 176	152 134 – 171

5.2 Adjustment coefficients and associated statistics

5.2.1 Height and age adjustment

Ratio-of-means adjustment factors were developed for inventory height and age in each stratum. These are shown in Tables 4 and 5 that follow. Correlation coefficients are also provided in these tables as a measure of the strength of the linear relationship between the audit and the inventory heights or ages.

With the exception of lodgepole pine leading stands, inventory heights generally showed a slight overestimation when compared with the ground heights. However, this overestimation was not more than about 6% in any of the strata. For lodgepole pine leading stands, the VRI sample indicated that inventory heights were quite close to ground heights, on average.

The analysis indicated that ages are typically overestimated in the inventory. The magnitude of overestimation ranges from 7% (in the lodgepole pine stratum) to about 20% (in the wet and dry belt fir strata).

²³ Volume utilization is for live stems 12.5 cm+ dbh where the leading species was lodgepole pine, whitebark pine or deciduous and for live stems 17.5 cm+ dbh for all other leading species. All volumes are net of decay, waste and breakage (loss factors).

Table 4: Height adjustment factors (ratio of means), by strata.

<i>Strata</i> ²⁴	<i>n</i> ²⁵	Height adjustment: Ratio of means			
		Mean top height	Mean inventory ht	Correlation	Ratio of means adjustment factor and 95% confidence interval
Spruce, balsam, deciduous	31	22.1	22.7	0.653	0.975 0.865 – 1.086
Lodgepole pine	42	16.5	16.3	0.728	1.012 0.928 – 1.096
Dry belt fir	15	16.7	17.7	0.274	0.944 0.747 – 1.140
Wet belt fir	34	21.1	21.6	0.550	0.976 0.887 – 1.065

Table 5: Age adjustment factors (ratio of means), by strata.

<i>Strata</i>	<i>n</i> ²⁶	Age adjustment: Ratio of weighted means			
		Mean ground age	Mean inventory age	Correlation	Ratio of means adjustment factor and 95% confidence interval
Spruce, balsam, deciduous	32	172	198	0.362	0.867 0.728 – 1.006
Lodgepole pine	42	119	129	0.510	0.926 0.789 – 1.062
Dry belt fir	15	154	192	0.170	0.800 0.559 – 1.041
Wet belt fir	33	132	167	0.441	0.793 0.684 – 0.901

5.2.2 Volume adjustment

The adjustment factors for volume were derived for each stratum in a two-step process:

1. The adjustment factors in Tables 4 and 5 respectively were applied to the inventory heights and ages for the samples. Using these adjusted attribute values,

²⁴ The strata are determined from the leading species indicated by the inventory (i.e. map label).

²⁵ Where ground height information was missing, the sample was excluded from the ratio of means and hence the sample size may be reduced in some strata.

²⁶ Where ground age information was missing, the sample was excluded from the ratio of means and hence the sample size may be reduced in some strata.

inventory volumes for the samples were generated in VDYP. The volumes produced in this step are referred to as "attribute-adjusted" inventory volumes.

2. Adjustment factors for volume – ratios between the ground volume and the "attribute-adjusted" volume – were then calculated.

There are two important issues to note when applying the volume adjustment factors to the inventory file:

1. The volume adjustment factors must be applied to the "attribute-adjusted" inventory volumes, that is, the VDYP volumes obtained based on adjusted heights and ages.
2. The resulting adjusted inventory volumes will reflect the utilization for the ground volumes used to derive the volume adjustment factor.

The volume adjustment factors (ratio-of-means) that were developed are provided in Table 6.

Note that for each of the proposed height, age and volume adjustments, the adjusted values of the attribute were compared with the ground values in each stratum. The difference between the ground value and the adjusted value is called a residual value and can be used in the statistical evaluation of the adjustment. A complete analysis of the residual values associated with the age, height and volume adjustments was completed and the results of this analysis are provided in Appendices A-10 and A-11.

Table 6: Volume adjustment factors (ratio of means) based on loss factor volumes, by strata. Utilization at 12.5cm+ dbh net dwb for lodgepole pine and whitebark pine leading and 17.5cm+ dbh net dwb for all other species leading.

Strata	n	Volume adjustment: Ratio of weighted means			
		Mean ground volume/ha	Mean "attribute-adjusted" inventory volume/ha	Correlation	Ratio of means adjustment factor and 95% confidence interval
Spruce, balsam, deciduous	35	259	192	0.533	1.347 0.993 – 1.701
Lodgepole pine	42	156	144	0.726	1.086 0.880 – 1.292
Dry belt fir	16	77	71	0.059	1.092 0.404 – 1.779
Wet belt fir	35	168	138	0.341	1.213 0.888 – 1.539

5.3 Evaluation of the results based on target sampling errors

The original ground sampling plan specified a target sampling error of 10% for the vegetated, treed portion of the district.

To provide an indication of the sampling error achieved in the adjustment process, a comparison of the mean ground volumes and the mean unadjusted inventory volumes

were made. Overall, the sampling error for the Lillooet TSA was about 14%. The sampling error by strata is shown in Table 7.

Table 7: Comparison of ground volumes and unadjusted inventory volumes (loss factor), by strata and overall.

Strata	Mean volumes/ha ²⁷ (loss factor), ratios & 95% confidence interval for ratios					
	n	Ground volume/ha (net dwb)	Unadjusted inventory volume/ha (net dwb)	Ratio of means	95% CI for ratio	Sampling error (as % of ratio)
Spruce, balsam, deciduous	35	259	199	1.30	1.01 – 1.33	26%
Lodgepole pine	42	156	143	1.10	0.90 – 1.30	19%
Dry belt fir	16	77	82	0.94	0.34 – 1.54	63%
Wet belt fir	35	168	149	1.13	0.83 – 1.43	27%
Overall	128	178	152	1.17	1.01 – 1.17	14%

The sampling errors achieved were above the target levels set by the district. Appendix A-12 provides further information on the relationship between sample size, sampling error, and probability level. The stakeholders need to review these sampling error results in consideration of their current business needs and decide if additional sampling is required.

6 Preliminary results for NVAF and comparison with loss factors

Although the sampling for NVAF is not yet complete, preliminary net volume adjustment factors (one overall NVAF and one NVAF with 2 age strata) were developed based on the data collected thus far. Overall volume ratio using NVAF and loss factors are compared in Table 8. The stakeholders need to review these results in consideration of their current business needs to decide how this information is best used and if additional sampling is required.

²⁷ Volume utilization is for live stems 12.5 cm+ dbh where the leading species was lodgepole pine, whitebark pine or deciduous and for live stems 17.5 cm+ dbh for all other leading species. All volumes are net of decay, waste and breakage (loss factors).

Table 8: Volume ratio comparison of loss factors and NVAF, overall and by strata.

Strata	n	<i>Ratio of ground volume to inventory volume, where ground volume is calculated based on:</i>		
		LOSS FACTORS	SINGLE NVAF	NVAF WITH 2 AGE STRATA
		Ratio & SE% ²⁸	Ratio & SE%	Ratio & SE%
Spruce, balsam, deciduous	35	1.30 ± 26%	1.34 ± 25%	1.59 ± 26%
Lodgepole pine	42	1.10 ± 19%	1.05 ± 19%	1.17 ± 20%
Dry belt fir	16	0.94 ± 63%	0.86 ± 63%	0.97 ± 69%
Wet belt fir	35	1.13 ± 27%	1.04 ± 26%	1.17 ± 26%
Overall	128	1.17 ± 14%	1.14 ± 13%	1.31 ± 14%

7 Overview of results post-stratified by operability

Section 4.2 outlined the primary populations of interest for the analysis of the VRI data. The results that are presented in section 5 of this document focus on the vegetated treed population. However, because of their importance in the timber supply context the results for operable and inoperable are summarized below in Table 9. A complete set of adjustment factors (for age, height and "attribute-adjusted" volume) are presented for the alternative populations of interest²⁹ in Appendices A-3, A-4 and A-5.

²⁸ SE = sampling error at the 95% probability level

²⁹ e.g., operable; inoperable; excluding type id = 6 and deciduous

Table 9: Comparison of loss factor volume ratio results for vegetated treed, operable and inoperable populations.

Strata	Volume/ha Ratios ³⁰ by Population of Interest					
	All vegetated tree polygons		OPERABLE vegetated treed polygons		INOPERABLE vegetated treed polygons	
	n	Ratio & SE% ³¹	n	Ratio & SE%	n	Ratio & SE%
Spruce, balsam, deciduous	35	1.30 ± 26%	14	1.16 ± 32%	21	1.42 ± 42%
Lodgepole pine	42	1.10 ± 19%	31	1.07 ± 22%	11	1.21 ± 46%
Dry belt fir	16	0.94 ± 63%	7	0.66 ± 141%	9	1.45 ± 59%
Wet belt fir	35	1.13 ± 27%	19	0.75 ± 33%	16	1.56 ± 35%
Overall	128	1.17 ± 14%	71	0.99 ± 16%	37	1.44 ± 22%

Although the overall volume ratio for the entire vegetated treed population was 1.17, post-stratification of the samples by operability suggests that volumes for the operable landbase are generally accurate, whereas volumes in the inoperable landbase may be underestimated by about 44%.

Note that the sampling error of 16% for the operable landbase was higher than the target level of 10% set by the district. Appendix A-12 provides further information on the relationship between sample size, sampling error, and probability level. The stakeholders need to review these sampling error results in consideration of their current business needs and decide if additional sampling is required.

8 Application of results for TSR

The stakeholders have yet to determine how these results will be incorporated into the TSR process. If these results are used to adjust the base-case TSR planning file, a series of evaluations would be required to ensure that the adjustments developed from the sample produced similar results when applied to the population as a whole. Detailed criteria for evaluating the adjustment are still being developed, but are likely to include a series of comparisons of totals and averages by strata. It is recommended that the results of the TSR adjustment evaluation be appended to this report.

³⁰ Volume utilization is for live stems 12.5 cm+ dbh where the leading species was lodgepole pine, whitebark pine or deciduous and for live stems 17.5 cm+ dbh for all other leading species. All volumes are net of decay, waste and breakage (loss factors).

³¹ SE = sampling error at the 95% probability level

9 Appendices

A-1 NVAF Sampling in the Lillooet District

Lillooet TSA Net Volume Adjustment Factor (NVAF) Report

Executive Summary:

The Lillooet TSA NVAF has been calculated from an incomplete and relatively small random sample of 48 live trees from the 10 vegetated treed polygons located throughout the Lillooet TSA. The NVAF adjustment amounts to a 10% reduction in VRI ground sample live volumes and the difference between the estimate and the actual tree volume is due to taper equation at 6% and decay hidden from the VRI ground samplers at 4%. The 1976 Loss Factors (excluding breakage) appear to adequately estimating the losses due to decay and waste. The sample error for live trees is 12.6%.

The sample is not large enough to be post stratified with any confidence. However, there are some trends in the results by age group: namely trees of all ages found on immature samples with a 12% volume overestimation (primarily taper), and trees of all ages found on mature samples with a 11% volume underestimation (primarily taper). The 1976 decay and waste loss factors appear to be overestimating the losses for the trees on the mature samples. It is recommended that the sampling of the remaining 3 sample trees be completed and that a larger pre-stratified NVAF sample be conducted.

Introduction:

- Definition

The Net volume Adjustment Factor, NVAF, is an unbiased statistically valid adjustment made to the net merchantable volume per hectare of VRI ground samples. The adjustment corrects for hidden decay and errors inherent in the taper equations, net factor decision rules and cruisers measurements.

The net merchantable volume adjusted by the NVAF is net decay and waste only, where the net merchantable is defined as the sound wood fiber located between the stump (30 cm height) and the top (10 cm diameter inside bark) of the tree.

- Production

The NVAF is calculated from the weighted ratio of actual net sound wood volume to the estimate of net merchantable volume for a sample of trees selected randomly from across the inventory unit.

The actual net sound wood volume is obtained from volume and decay destructive sampling. The estimate of net sound wood volume is obtained from the VRI plot compiler.

- Application

The NVAF is applied at the end of the VRI plot compiler process and is used as a multiplier of the VRI sample plot volume per hectare.

Sample Design:

- Two NVAF adjustments were envisaged, one for all live trees and the other for dead trees.
- The population was defined as all trees with a dbh greater than 12.5 dm dbh found on vegetated treed polygons in the Lillooet TSA and all portions of this area had an equal chance of selection.
- The NVAF sample has two distinct steps:
 - Step One: The random selection of a subset of VRI ground samples and the enhancement of all live and dead trees (dbh ≥ 4 cm) in the auxiliary plots of the selected samples.

Step Two: The selection of NVAF sample trees, using a matrix consisting of 3 broad diameter classes, and the destructive sampling of the selected trees.

- **Project Details:**

Step One- Number of VRI ground samples: 15

(Note: Of the 15 samples, only 13 samples were found to have contain trees ≥ 12.5 cm dbh.)

Step Two – Number of NVAF sample trees: 51 live trees and 3 dead trees from 12 of the ground samples.

(Notes:

1. Only 48 live trees were successfully sampled. There are 3 trees from one ground sample remaining to sample.

2. The selection of dead trees departed from the regular process. An auxiliary plot was randomly selected from each NVAF ground sample and one dead tree randomly selected from the selected auxiliary plot.)

Sample Distribution:

Since the samples and sample trees were selected randomly, the distribution of the NVAF trees by age and species was compared to the overall population. The comparison is shown in table 1. The sample was found to be disproportionate in the following:

- Undersampled mature samples and oversampled immature samples
- In immature samples, there is an undersampling of balsam and spruce. There is an oversampling of cottonwood and Lodgepole pine.
- In mature samples, there is an undersampling of balsam, spruce, Lodgepole pine and whitebark pine. There is an oversampling of Douglas-fir.

Table 1. Lillooet TSA Inventory and NVAF Sample Comparison *

Species	% immature volume**	Number of NVAF sample trees	% mature volume**	Number of NVAF sample trees
Ac	1	2	0	0
At	0	0	0	0
B	23	1	26	3
C	7	2	0	0
Fd	44	7	25	15
H	0	0	0	0
Pa	5	0	4	0
Pl	37	11	22	1
Pw	0	0	0	0
Py	4	0	1	0
S	25	3	20	3

* source: Compiled net merchantable volume per hectare of VRI ground samples.

** age group is based on average sample age using 120 years as the age group boundary.

The results:

The NVAF data was routinely post-stratified by species and age group in order to detect and explore trends in the results. The actual volumes of the samples were compared to the estimates of net merchantable volume obtained from the VRI net factor process and the also the 1976 Loss Factors (excluding breakage). Table 2 contains a summary of the results by species and age group. Table 3 shows the statistical analysis.

Note that the sample size and distribution is too limited to allow for post stratification of the NVAF adjustment.

Table 2. Lillooet TSA NVAF Ratios by Species and Age Groupings

Adjustment Type	No. of trees	No. Of Samples	Net Volume Adjustment Factor (2)	Average Difference in Loss Factor Estimates (3)	Average Difference of Taper Equation (4)
(post stratification)					
All Live Trees (1)	48	10	.90	.94	.94
All Dead Trees (1)	3	3	.92	1.74	.94
Live Tree Strata:					
Trees age < 120 years	24	6	.88	.91	.9
Trees age > 120 years	24	8	.91	.95	.95

Lillooet Vegetation Resources Inventory Analysis Report

Sample age < 120 years	26	7	.79	.81	.86
Sample age > 120 years	22	3	1.11	1.19	1.09
Ac (< 120 years)	2	1	.8	2.13	.9
B	4	3	1.01	1.15	1.03
B age < 120 years	2	1	1.02	1.05	1.06
B age > 120 years	2	2	1.01	1.23	1.01
B < 120 sample age	1	1	1.0	1.26	1.0
B > 120 sample age	3	2	1.02	1.09	1.05
C (< 120 sample age)	2	1	1.01	1.21	1.06
Fd	22	6	.88	.9	.92
Fd age < 120 years	9	3	.83	.84	.84
Fd age > 120 years	13	5	.89	.91	.93
Fd < 120 sample age	7	4	.72	.72	.8
Fd > 120 sample age	15	2	1.14	1.24	1.11
Pl	12	4	.97	1.0	.98
Pl age < 120 years	10	2	.95	.96	.96
Pl age > 120 years	2	2	1.16	1.3	1.16
Pl < 120 sample age	11	3	.95	.97	.97
Pl > 120 sample age	1	1	1.17	1.32	1.17
S	6	4	.95	.99	.99
S age < 120 years	1	1	1.08	1.1	1.12
S age > 120 years	5	3	.95	.98	.96
S < 120 sample age	3	2	.93	.98	1.04
S > 120 sample age	3	2	.96	.99	.97

Table 2 Notes:

- (1) The NVAF adjustment type to be used in the VRI plot compiler.
- (2) NVAF Adjustment for use in the VRI plot compiler, where the estimate of net merchantable volume is obtained from net factoring and the taper equation.
- (3) Difference between the actual and the net merchantable volume estimated by the 1976 Loss Factor system. A number less than 1.0 indicates an overestimate. For example, the live tree value is 0.94 and

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indicates that the loss factors and taper equation together are overestimating net merchantable volume by 6%.

- (4) Difference between the actual and the estimate of gross merchantable volume produced by the taper equations. A number less than 1.0 indicates an overestimate. For example, the live tree value is 0.94 and indicates that the taper equation is overestimating gross merchantable volume by 6%.

Table 3. Statistical Analysis of the NVAF Data

Stratum	NVAF	Sample Size	Sample Error % of the NVAF	Confidence Limits (19 times out of 20)	Number of Trees required for 5% Sample Error
All Live Trees	.902	48	12.6	.845 - .958	306
All Live Immature (<120 years of sample)	.789	26	10.3	.746 - .827	112
All Live Mature (> 120 years of sample)	1.107	22	7.0	1.069 - 1.146	43
species with sample sizes of 10 trees or more					
Pl	.972	12	4.9	.949 - .996	12
Fd	.878	22	19.9	.791 - .965	348
Sample Age and species groups with sample sizes of 10 trees or more					
Immature Pl	.955	11	4.3	.934 - .975	9
Mature Fd	1.138	15	5.6	1.106 - 1.170	19

Interpretation of the results:

1. Overall, combining all live sample trees together, the VRI (taper and net factoring) estimates of net merchantable volume are on average overestimating the sound wood volume in the merchantable portion of the tree by 10%. The majority of this difference, 6%, is due to the taper equation and the remaining 4% is due to hidden decay. By comparison, the Loss Factor system of estimating net merchantable volume appears to be adequately estimating the losses to sound wood volume.
2. The sample error for the entire live tree sample is quite large and supports the need for additional sampling and stratification.
3. Post stratification of the data into age groups and species, shows that there are trends in the adequacy of the estimates of gross volume and for the deductions for losses to sound wood volume and net merchantable volume. However, the sample size is quite small and the number of sample locations is too few to draw definite conclusions on the ability of the tree based equations to estimate net merchantable volume.
4. Trends by species and age groups, as per table 4.

Table 4. Details of the NVAF Results by Species and Age Groups

Species	Trends
Fd	Tree age is not closely related to sample age. In general, there are no sound wood losses in immature trees and in many of the mature sample trees. VRI net factoring was able to accurately estimate sound wood losses for all the immature trees and most of the mature trees. There was a general overestimation of decay and waste by the 1976 Loss Factors in immature and most of the mature trees. The results of the taper equations were variable by tree age but were consistently over or under estimating gross volume when stratified by sample age. Taper overestimated the gross volume of trees in immature samples and underestimated the gross volume of trees in mature samples.
Pl	There was no losses to sound wood from decay or waste in any of the sample trees. The VRI net factoring was able to accurately estimate the sound wood losses but the 1976 Loss Factors assigned small amounts of decay and waste to each tree, so consequently overestimated sound wood losses. The taper equation appears to slightly overestimate the gross volume of the immature trees and may be underestimating the gross volume of the mature trees.
Other species	Too small a sample to detect any trends in the estimates.

Adjustment Options:

Use the existing 1976 Loss Factors as an interim deductions for decay and waste. Do not consider using the NVAF results until the remaining sample is complete.

Sampling Options:

1. Complete the existing sample plan by sampling the remaining 3 Fd sample trees in Sample 90 and conduct no additional sampling.
2. Complete the remaining sample and conduct additional sampling. Consider stratification by species, age groups or BEC units.

Will Smith, RPF
Volume and Decay Sampling Officer
Resources Inventory Branch
October 12, 2000

Lillooet Vegetation Resources Inventory Analysis Report

A-2 Quality Assurance Results

Vegetation Resources Inventory

Quality Assurance - Tree Values - Audit versus Original: Report PT8

Sample Measurement Dates: 1998-1999

Project Id: DLL1

Report Version : 1.0

Project Name: Lillooet FD/Ainsworth

of Original samples :126

Type: Q (Timber Emphasis Sample)

of Audit Samples : 12

% Audited : 9.5%

Samp #	Orig. Crew Leader	Audit Crew leader	Orig. Gross Vol/Ha.	Audit Gross Vol/Ha.	Diff. Gross Vol/Ha. (3)	% Gross Vol Diff. (4)	Orig. Net Merch Vol/Ha. (1)	Audit Net Merch Vol/Ha. (1)
57	SJW	LEW	110.0	105.5	4.4	4.2%	58.4	54.7
58	WAM	VAS	42.8	40.7	2.2	5.3%	37.1	35.0
59	SJW	LEW	60.1	55.7	4.4	7.9%	24.8	26.4
69	WAM	LEW	4.9	5.1	-0.1	(2.1%)	4.5	4.6
78		LEW	.	135.3	.	.	.	57.6
90	WAM	LEW	29.1	31.0	-1.9	(6.2%)	9.1	8.8
104	WAM	VAS	29.1	28.7	0.5	1.6%	27.5	27.0

Sample #	Diff. Net Merch Vol/Ha. (3)	Net Merch Vol Diff. (4)	\$ Orig Value/Ha. (2)	\$ Audit Value/Ha. (2)	\$ Diff Value/Ha. (3)	% Value Diff. (4)
57	3.7	6.7%	\$3,220	\$2,646	\$574	21.7%
58	2.1	5.9%	\$1,605	\$1,328	\$277	20.9%
59	-1.6	(6.1%)	\$1,591	\$1,791	\$-200	(11.2%)
69	-0.1	(2.2%)	\$110	\$114	\$-5	(4.1%)
78	.	.	.	\$3,795	.	.
90	0.3	3.4%	\$405	\$301	\$105	34.8%
104	0.4	1.6%	\$1,437	\$1,536	\$-99	(6.4%)

All gross volumes (m3/ha) are for all stems live and dead, at 4 cm +

All net volumes and value are calculated using live stems only at 4 cm +

1. Net volume (live): gross vol./ha (m3) less cruiser called net factor, 30 cm stump and 10 cm top

2. Calculated dollar value/ha for all live stems based on net volume

3. Volume difference is audit volume less original volume

4. Percent difference is difference / audit value

** Report Contact : Growth and Yield Data Analyst: Alf Kivari Produced on: October 17, 2000

Lillooet Vegetation Resources Inventory Analysis Report

Vegetation Resources Inventory

Quality Assurance - Tree Values - Audit versus Original: Report PT8

Sample Measurement Dates: 1998-1999

Project Id: DLL1

Report Version : 1.0

Project Name: Lillooet FD/Ainsworth

of Original samples :126

Type: Q (Timber Emphasis Sample)

of Audit Samples : 12

% Audited : 9.5%

Sample #	Orig. Crew Leader	Audit Crew leader	Orig. Gross Vol/Ha.	Audit Gross Vol/Ha.	Diff. Gross Vol/Ha. (3)	% Gross Vol Diff. (4)	Orig. Net Merch Vol/Ha. (1)	Audit Net Merch Vol/Ha. (1)
114	SJW	LEW	108.9	104.4	4.5	4.3%	72.9	70.0
115	SJW	LEW	178.7	185.3	-6.6	(3.6%)	22.8	24.3
130	WAM	LEW	14.8	16.8	-2.0	(11.8%)	1.4	2.6
136	WAM	LEW	191.8	197.4	-5.6	(2.8%)	40.3	36.0
144	SJW	LEW	448.1	450.1	-2.1	(0.5%)	309.0	315.9
Means			110.7	113.0	-2.2	(2.0%)	55.2	55.3

Sample #	Diff. Net Merch Vol/Ha. (3)	% Net Merch Vol Diff. (4)	\$ Orig Value/Ha. (2)	\$ Audit Value/Ha. (2)	\$ Diff Value/Ha. (3)	% Value Diff. (4)
114	2.8	4.0%	\$3,256	\$3,048	\$207	6.8%
115	-1.5	(6.1%)	\$228	\$243	\$-15	(6.1%)
130	-1.3	(48.4%)	\$27	\$52	\$-25	(48.4%)
136	4.2	11.8%	\$3,255	\$3,612	\$-357	(9.9%)
144	-6.9	(2.2%)	\$14,808	\$18,521	\$-3,713	(20.0%)
Means	-0.0	(0.0%)	\$2,722	\$3,082	\$-360	(11.7%)

All gross volumes (m3/ha) are for all stems live and dead, at 4 cm +

All net volumes and value are calculated using live stems only at 4 cm +

1. Net volume (live): gross vol/ha (m3) less cruiser called net factor, 30cm stump and 10cm top
2. Calculated dollar value/ha for all live stems based on net volume
3. Volume difference is audit volume less original volume
4. Percent difference is difference / audit value

** Report Contact: Growth and Yield Data Analyst: Alf Kivari Produced on: October 17, 2000

A-3 Adjustment factors for OPERABLE vegetated treed polygons

Table 1: Height adjustment ratios (ratio of means), by strata for VT OPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means height adjustment</i>			
		Mean ground height	Mean inventory height	Correlation	Ratio of means
Spruce, Balsam, Decid.	13	24.0	24.8	0.425	0.967
Lodgepole pine	31	17.0	16.8	0.778	1.012
Dry belt fir	6	17.0	20.1	0.222	0.845
Wet belt fir	18	19.0	21.2	0.618	0.898

Table 2: Age adjustment ratios (ratio of means), by strata for VT OPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means age adjustment</i>			
		Mean ground age	Mean inventory age	Correlation	Ratio of means
Spruce, Balsam, Decid.	13	162	194	0.288	0.835
Lodgepole pine	31	114	119	0.533	0.958
Dry belt fir	6	154	177	-0.019	0.872
Wet belt fir	17	139	158	0.469	0.880

Table 3: Volume adjustment ratios (based on loss factor volumes), by strata for VT OPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means volume adjustment</i>			
		Mean ground volume/ha	Mean "attribute-adjusted" inventory volume/ha	Correlation	Ratio of means
Spruce, Balsam, Decid.	14	270	221	0.674	1.224
Lodgepole pine	31	165	156	0.751	1.055
Dry belt fir	7	80	80	-0.350	1.000
Wet belt fir	19	110	118	0.389	0.935

A-4 Adjustment factors for INOPERABLE vegetated treed polygons

Table 1: Height adjustment ratios (ratio of means), by strata for VT INOPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means height adjustment</i>			
		Mean ground height	Mean inventory height	Correlation	Ratio of means
Spruce, Balsam, Decid.	18	20.8	21.1	0.739	0.983
Lodgepole pine	11	15.1	15.0	0.438	1.011
Dry belt fir	9	16.6	16.1	0.353	1.026
Wet belt fir	16	23.4	22.1	0.476	1.060

Table 2: Age adjustment ratios (ratio of means), by strata for VT INOPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means age adjustment</i>			
		Mean ground age	Mean inventory age	Correlation	Ratio of means
Spruce, Balsam, Decid.	19	179	201	0.430	0.888
Lodgepole pine	11	134	157	0.444	0.858
Dry belt fir	9	153	202	0.311	0.758
Wet belt fir	16	125	176	0.502	0.710

Table 3: Volume adjustment ratios (based on loss factor volumes), by strata for VT INOPERABLE.

<i>Strata</i>	<i>n</i>	<i>Ratio of means volume adjustment</i>			
		Mean ground volume/ha	Mean "attribute-adjusted" inventory volume/ha	Correlation	Ratio of means
Spruce, Balsam, Decid.	21	251	173	0.468	1.453
Lodgepole pine	11	133	112	0.588	1.188
Dry belt fir	9	75	55	0.558	1.371
Wet belt fir	16	236	163	0.442	1.449

A-5 Adjustment factors for vegetated treed polygons excluding those classed as non-productive forest (type id = 6)

Excludes "non-productive" (type id=6) samples and AT leading sample (n=114)

Table 1: Height adjustment ratios (ratio of means), by strata (type id=6 and AT leading excluded).

Strata	n	Ratio of means height adjustment				
		Mean ground height	Mean inventory height	Correlation	Ratio of means	95% CI for ratio
Spruce, Balsam	25	23.2	25.0	0.629	0.929	0.824 – 1.034
Spruce ³²	13	25.0	28.1	0.705	0.890	0.595 – 1.102
Balsam	12	21.3	21.7	0.482	0.984	0.773 – 1.194
Lodgepole pine	39	16.8	16.5	0.758	1.021	0.940 – 1.102
Dry belt fir	14	16.3	17.9	0.326	0.912	0.717 – 1.107
Wet belt fir	32	21.2	21.6	0.553	0.981	0.887 – 1.076

Table 2: Age adjustment ratios (ratio of means), by strata (type id=6 and AT leading excluded).

Strata	n	Ratio of means age adjustment				
		Mean ground age	Mean inventory age	Correlation	Ratio of means	95% CI for ratio
Spruce, Balsam	25	188	211	0.254	0.893	0.735 – 1.051
Spruce ³³	13	188	222	0.087	0.848	0.595 – 1.102
Balsam	12	189	199	0.481	0.947	0.737 – 1.157
Lodgepole pine	39	120	123	0.587	0.982	0.840 – 1.123
Dry belt fir	14	155	191	0.177	0.813	0.551 – 1.076
Wet belt fir	31	133	166	0.450	0.802	0.684 – 0.918

³² Separate means and ratios were calculated based on a separate strata for spruce-leading only and another strata for balsam-leading only.

³³ Separate means and ratios were calculated based on a separate strata for spruce-leading only and another strata for balsam-leading only.

Table 3: Volume adjustment ratios (based on loss factor volumes), by strata (type id=6 and AT leading excluded).

<i>Strata</i>	<i>n</i>	<i>Ratio of means volume adjustment</i>				
		Mean ground volume/ha	Mean "attribute-adjusted" inventory volume/ha	Correlation	Ratio of means	95% CI for ratio
Spruce, Balsam	27	287	221	0.527	1.298	0.946 – 1.650
Spruce ¹⁴	14	338	251	0.447	1.348	0.823 – 1.873
Balsam	13	231	185	0.547	1.250	0.709 – 1.790
Lodgepole pine	39	162	151	0.730	1.072	0.864 – 1.280
Dry belt fir	15	76	69	0.076	1.104	0.368 – 1.839
Wet belt fir	33	175	143	0.326	1.221	0.890 – 1.552

¹⁴ Separate means and ratios were calculated based on a separate strata for spruce-leading only and another strata for balsam-leading only. "Attribute-adjusted" volumes in the 'spruce only' and 'balsam only' strata are based on heights and ages adjusted using the 'spruce only' and 'balsam only' ratios for height and age in Tables 1 and 2.

A-6 Data Issues Log

Sample #	Issue	Action
59	Ground height but no ground age available.	Use ht; consider age missing.
67	No ground spp. composition (hence no lead spp. By ba) but ground hts and age data available	Use PA ht and age data as there were 2 Pa ht/age samples and only 1 S
85	No ground ht or age avail for leading (Pa) or 2 nd spp (BI); ht & age available for 3 rd spp (S)... can this be used?	Use no ht/age because the alternative was to use 3 rd species and not acceptable.
96	Ground age but no height available.	Use age; consider height missing.
106	No ground hts or ages available; call missing?	Use no ht/age data
126	No ground hts or ages available; call missing?	Use no ht/age data
167	GROUND ATTRIBUTES: at 17.5cm+, FD50PL50; at 12.5cm+, PL53FD47; FD age=91 ht=21.4; PI age=143 ht=20.7; use Fd ht and age?	Use PI age/ht as there were 4 PL and 1 Fd.
170	No ground hts or ages available; call missing?	Use no ht/age data
173	GROUND ATTRIBUTES: at 17.5cm+, PI57BI43; at 12.5cm+, BI50PI50; PI age=244 ht=15.1; BI age=75 ht=11.3; use PI ht and age?	Use PI because PL leading at 17.5
182	No ground hts or ages available; call missing?	Use no ht/age data
67, 148, 151, 153	Ownership is 68N; are these samples in the population of interest?	Use all data in initial summary. Type id 6 may be excluded in future analysis.
71	Ownership is 69N; is this sample in the population of interest?	Use all data in initial summary. Type id 6 may be excluded in future analysis.
82, 124, 140	Ownership is 40N; are these samples in the population of interest?	Use all data in initial summary. Type id 6 may be excluded in future analysis.
113	Ownership is 61N; is this sample in the population of interest?	Use all data in initial summary. Type id 6 may be excluded in future analysis.
61, 65, 66, 67, 85, 95, 96, 100, 101, 112, 127, 130, 165, 168	Type identification = 6 (non-productive) Are these samples in the population of interest?	Use all data in initial summary. Type id 6 may be excluded in future analysis.
56, 168	Samples were replaced in same polygon.	No action required
61, 62, 67, 88, 105, 109, 116, 127	Samples were replaced in different polygons.	Confirm with Sam that replacement polygon inventory attributes should be used in analysis. OK. Get replacement polygon attributes from Gary DONE .

A-7 List of VRI reports summarizing ecological and other timber attributes

(For more information, please contact Resources Inventory Branch)

Name	Description
Sample Data Listings - for verification of input	
LL1	location Details
LT1	Large Tree Summary
LT2	Small Tree and Stump Data
LT3	Top Height and Site Tree Data
LT4	Damage Agents and Loss Indicators
LT5	Stem Map Data
LE1**	Ecological Data
LR1**	Range Data
LC1**	Coarse Woody Debris
Sample Cluster Reports	
CT1	Timber Summary
CE1**	Ecological Summary
CC1**	Coarse Woody Debris Summary
CR1**	Range Summary
Project reports	
PS1	Sample Plot Information
PT1	Tree Counts
PT2	Gross/Net Volume by Species and Utilization Limit
PT3	Log Grade Distribution by Species
PT4	Piece Size Distribution by Species
PT5	Forest Health Information
PT6	Wildlife Tree Information
PT7**	Old Growth and Succession Information
PE1**	Ecological Information
PC1**	Coarse Woody Debris Information (6 part report)
PR1**	Range Information
PB1**	Woody Biomass Volumes
PT8	Quality Assurance Report
PT9	Quality Control report

**** Data for these reports were not collected for the Lillooet TSA.**

A-8 Plots of ground height and age versus inventory height and age, by strata (all vegetated treed polygons)

Ground Age versus Unadjusted Inventory Age

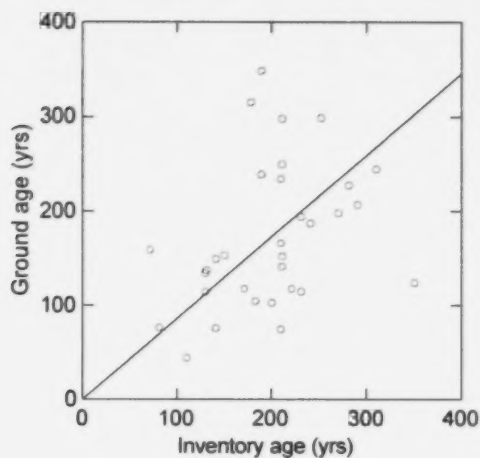


Fig. 1: Spruce, Balsam, Deciduous

Ground age vs. unadjusted inventory age. The line on the graph represents the ratio of means.

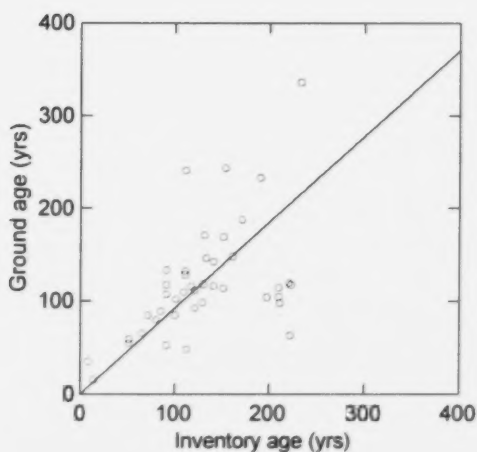


Fig. 2: Lodgepole pine

Ground age vs. unadjusted inventory age. The line on the graph represents the ratio of means.

Ground Age versus Unadjusted Inventory Age

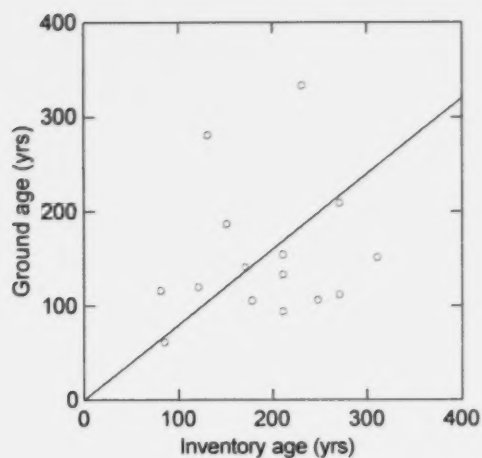


Fig. 3: Drybelt fir
Ground age vs. unadjusted inventory age. The line on the graph represents the ratio of means.

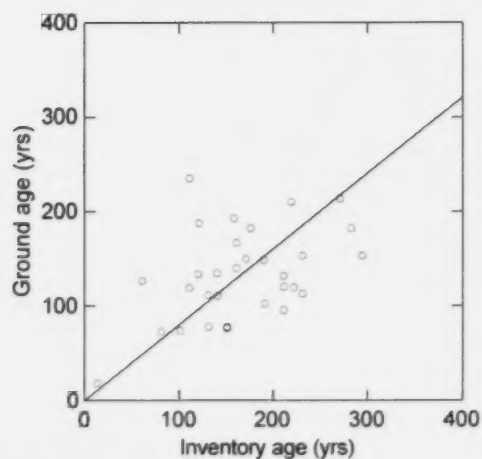


Fig. 4: Wetbelt fir
Ground age vs. unadjusted inventory age. The line on the graph represents the ratio of means.

Ground Height versus Unadjusted Inventory Height

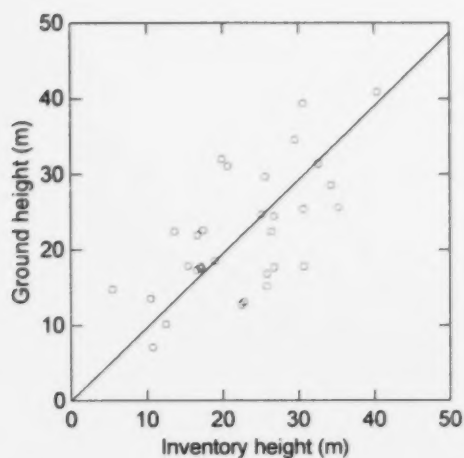


Fig. 5: *Spruce, Balsam, Deciduous*
Ground height vs. unadjusted inventory height. The line on the graph represents the ratio of means.

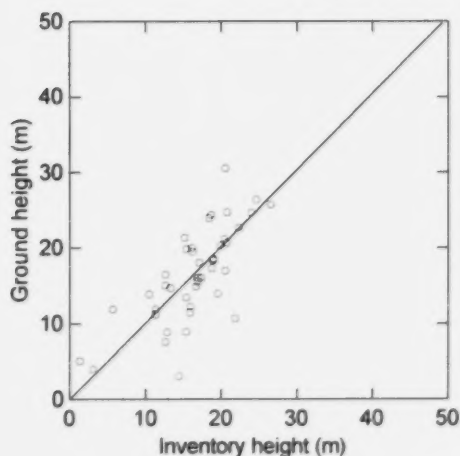


Fig. 6: *Lodgepole pine*
Ground height vs. unadjusted inventory height. The line on the graph represents the ratio of means.

Ground Height versus Unadjusted Inventory Height

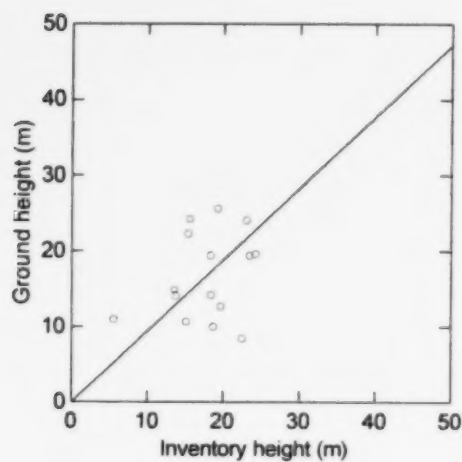


Fig. 7: Drybelt fir
Ground height vs.
unadjusted inventory
height. The line on the
graph represents the ratio
of means.

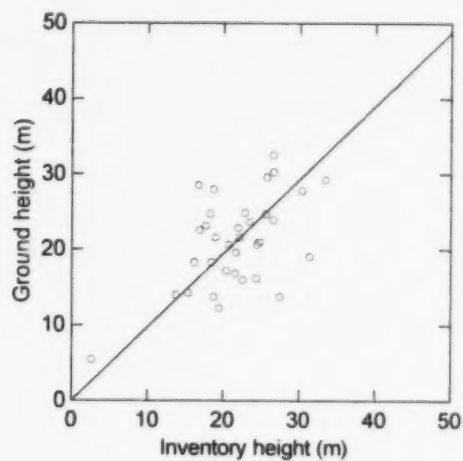


Fig. 8: Wetbelt fir
Ground height vs.
unadjusted inventory
height. The line on the
graph represents the ratio
of means.

A-9 Plots of ground volume versus "attribute-adjusted" inventory volume, by strata (all vegetated treed polygons)

*Ground volume (loss factors) versus "attribute-adjusted" inventory volume
(i.e. inventory volume based on ratio-adjusted heights and ages)*

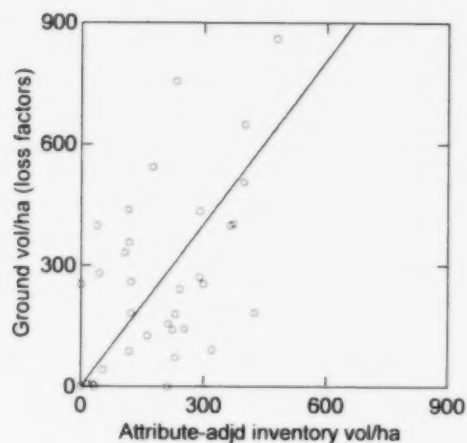


Fig. 17: Spruce, Balsam, Deciduous
Ground volume (17.5cm+ for S&B leading; 12.5cm+ for decid leading) versus "attribute-adjusted" inventory volume. The line on the graph represents the ratio of means.

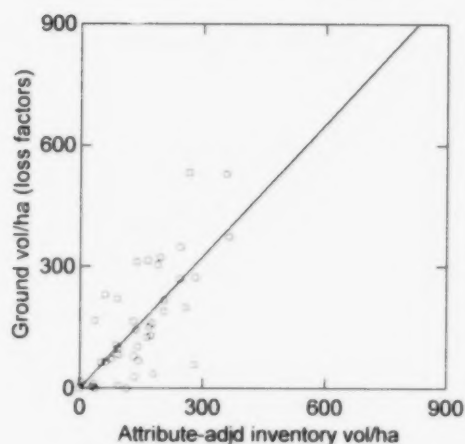


Fig. 18: Lodgepole pine
Ground volume (12.5cm+ for Pl and Pa leading) versus "attribute-adjusted" inventory volume. The line on the graph represents the ratio of means.

***Ground volume (loss factors) versus "attribute-adjusted" inventory volume
(i.e. inventory volume based on ratio-adjusted heights and ages)***

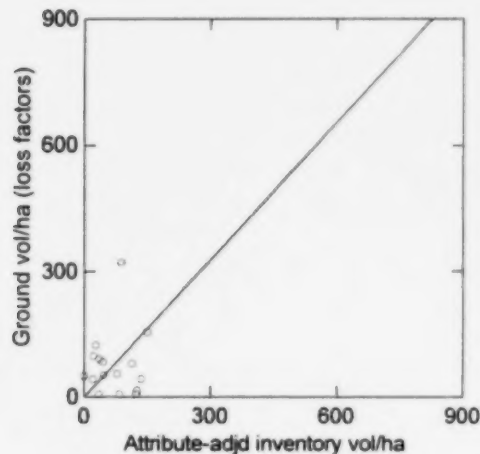


Fig. 19: Drybelt fir
Ground volume (17.5cm+
for Fd and Py leading)
versus "attribute-adjusted"
inventory volume. The
line on the graph
represents the ratio of
means.

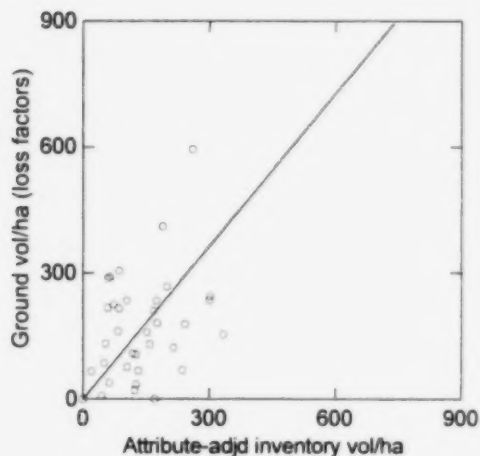


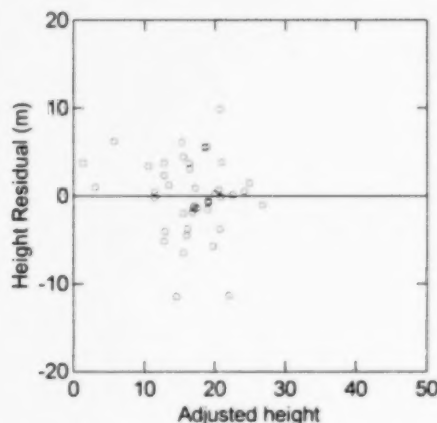
Fig. 20: Wetbelt fir
Ground volume (17.5cm+
for Fd leading) versus
"attribute-adjusted"
inventory volume. The
line on the graph
represents the ratio of
means.

A-10 Residuals Analysis

For each of the proposed height, age and volume adjustments, the adjusted values of the attribute were compared with the ground values in each stratum. The difference between the ground value and the adjusted value is called a residual value³⁵. Residual values were plotted against the adjusted values to evaluate potential bias associated with the adjustment. A complete set of the plots of residuals versus adjusted values is provided in Appendix A-11.

For most attributes and most strata, the residuals are distributed in an approximately even horizontal band across the range of adjusted values. Figure 1 below illustrates this pattern. This horizontal band of residuals indicates an unbiased fit for the ratio adjustment.

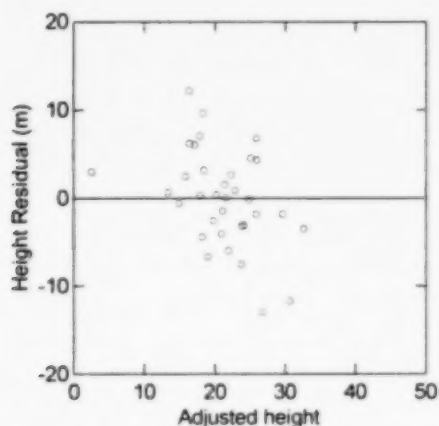
Figure 1: Plot of residual values versus adjusted height for the lodgepole pine stratum.



However, in some strata, the pattern of residuals indicated potential bias associated with the ratio adjustment model. As can be seen in Figure 2, there is a downward sloping trend in the residuals in some strata. This indicates that the ratio adjustment tends to underestimate heights in short stands and overestimate heights in tall stands. Such a trend in the residuals means that the ratio-of-means model may not be appropriate for height adjustment in this stratum.

³⁵ Residual value = ground value - adjusted value.

Figure 2: Plot of residuals values versus adjusted height for the wetbelt fir stratum.



To correct for this potential bias, various alternative adjustment models were considered. In particular, least squares regression (LSR) and geometric mean regression (GMR) for height adjustment in the wetbelt fir stratum were examined as a potential alternatives to ratio-of means.

Table 10: Alternative GMR and LSR height adjustment for Balsam strata.

<i>Strata</i>	<i>n</i>	<i>GMR</i>		<i>LSR</i>	
		<i>Intercept</i>	<i>Slope</i>	<i>Intercept</i>	<i>Slope</i>
Wet belt fir	32	-1.230	1.038	8.808	0.574

A similar pattern of bias was observed using a ratio-of-means adjustment for age in this stratum. Hence, LSR and GMR were also used to adjust ages (Table 11).

Table 11: Wetbelt fir stratum LSR and GMR adjustment for age.

<i>Strata</i>	<i>n</i>	<i>GMR</i>		<i>LSR</i>	
		<i>Intercept</i>	<i>Slope</i>	<i>Intercept</i>	<i>Slope</i>
Wet belt fir	31	7.405	0.758	76.713	0.341

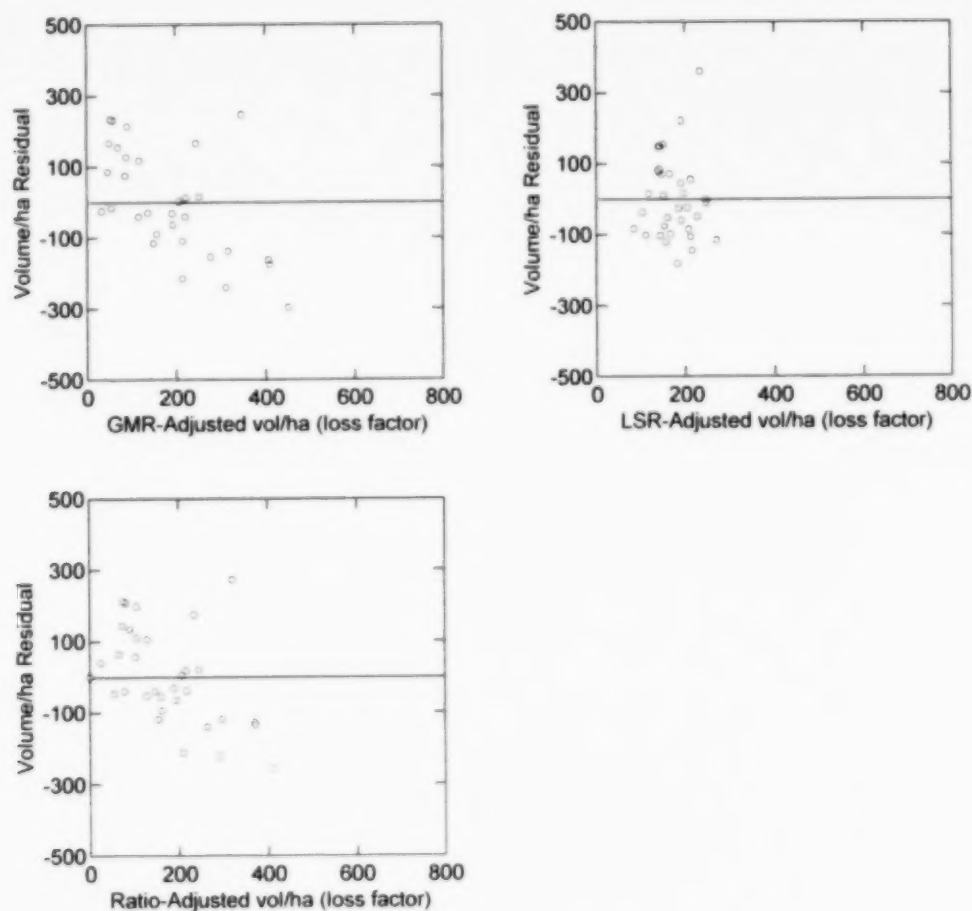
Based on these alternative adjusted ages and heights, inventory volumes were calculated in VDYP. A LSR and GMR approach for volume adjustment was then examined (see Table 12). Note that the same adjustment methodology was maintained for each of the height, age and volume adjustments.

Table 122: Wetbelt fir stratum LSR and GMR adjustment for volume (using corresponding adjustment methodology for age and height)

<i>Strata</i>	<i>n</i>	<i>GMR</i>		<i>LSR</i>	
		<i>Intercept</i>	<i>Slope</i>	<i>Intercept</i>	<i>Slope</i>
Wet belt fir	33	-27.321	1.388	74.957	0.710

The GMR and LSR-adjusted volume residuals, generated from the Table 12 were then compared with the ratio of means-adjusted volume residuals. These residuals plots are shown in Figure 3.

Figure 3: Adjusted volume/ha residuals plots for GMR, LSR, and ratio-adjusted volume.



In the wetbelt fir stratum in the Lillooet VRI data, the apparent bias using a ratio-of-means height adjustment also appeared in the ratio-adjusted volumes. However, the two alternative adjustment approaches examined (i.e., GMR and LSR) either were unable to correct for this bias trend or resulted in other prediction anomalies. For example, both the GMR and the LSR produced significant intercept values that could have implications if applied in the TSR context. In addition, the LSR approach resulted in very "flat" adjustment (high intercept and low slope) that greatly restricted the range of predicted values. Despite the recognized bias trend, ratio-of-means was seen as a more conservative adjustment approach. As a result, ratio-of-means was recommended for age, height and volume in all strata in this analysis. However, further study of alternative adjustment methodologies and potential implications for their usage is recommended. Note also that the potential implications for site index caused by the bias trend in the ratio-of-means height adjustment are unclear.

A-11 Residuals plots

RESIDUALS PLOTS FOR AGE

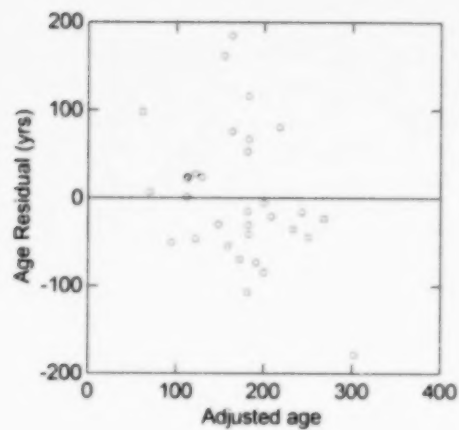


Fig. 1: *Spruce, Balsam, Deciduous.*
Residuals for predicted age
(i.e. ratio-adjusted age).

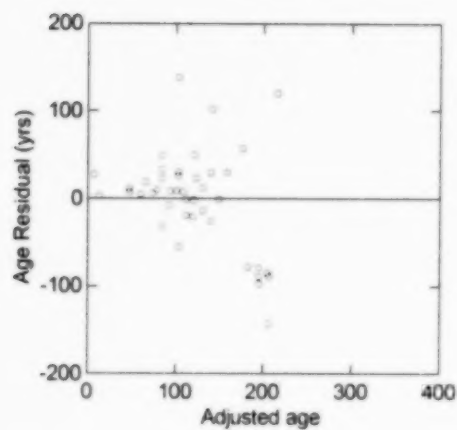


Fig. 2: *Lodgepole pine*
Residuals for predicted age
(i.e. ratio-adjusted age).

RESIDUALS PLOTS FOR AGE

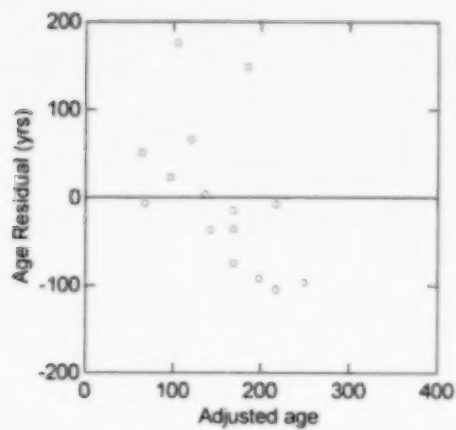


Fig. 3: Drybelt fir
Residuals for predicted age
(i.e. ratio-adjusted age).

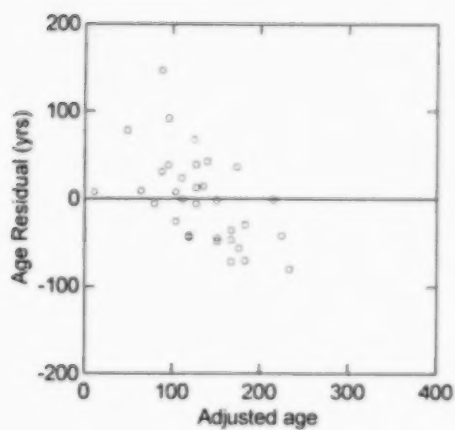


Fig. 4: Wetbelt fir
Residuals for predicted age
(i.e. ratio-adjusted age).

RESIDUALS PLOTS FOR HEIGHT

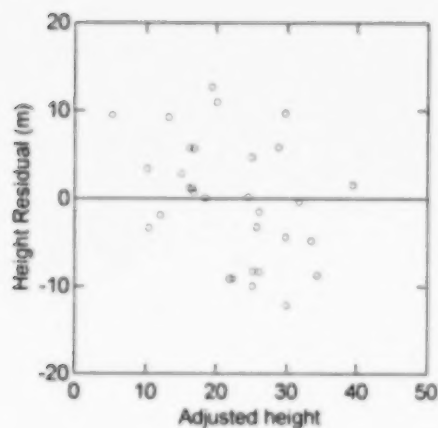


Fig. 5: Spruce, Balsam, Deciduous.

Residuals for predicted height (i.e. ratio-adjusted height).

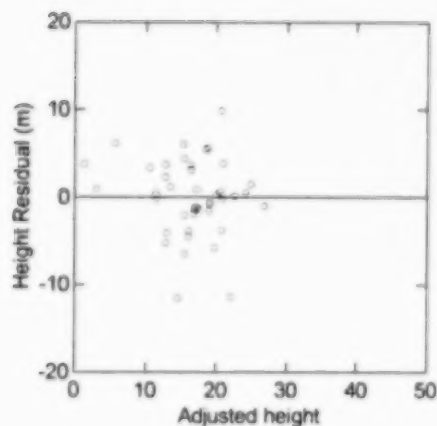


Fig. 6: Lodgepole pine

Residuals for predicted height (i.e. ratio-adjusted height).

RESIDUALS PLOTS FOR HEIGHT

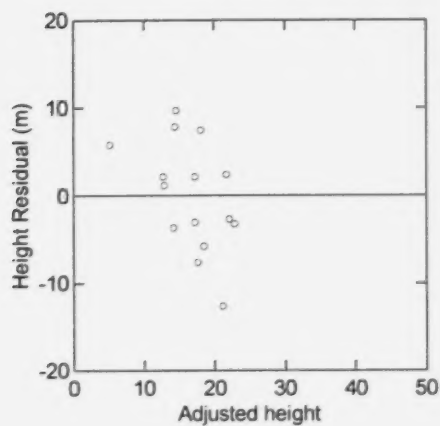


Fig. 7: Drybelt fir
Residuals for predicted
height (i.e. ratio-adjusted
height).

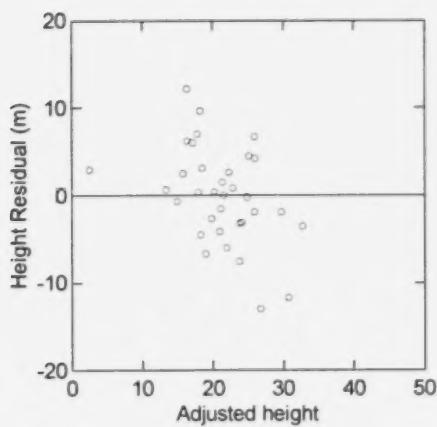


Fig. 8: Wetbelt fir
Residuals for predicted
height (i.e. ratio-adjusted
height).

RESIDUALS PLOTS FOR RATIO-ADJUSTED VOLUME (loss factor)

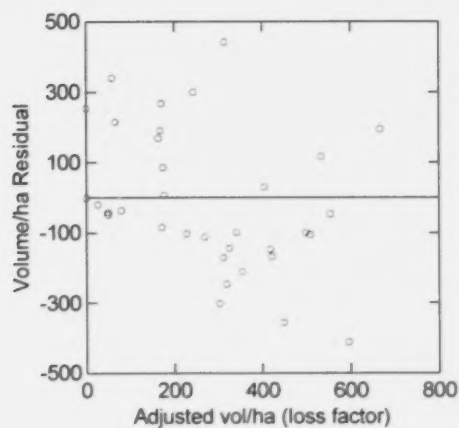


Fig. 25: *Spruce, Balsam, Deciduous*
Residuals for ratio-adjusted volume.

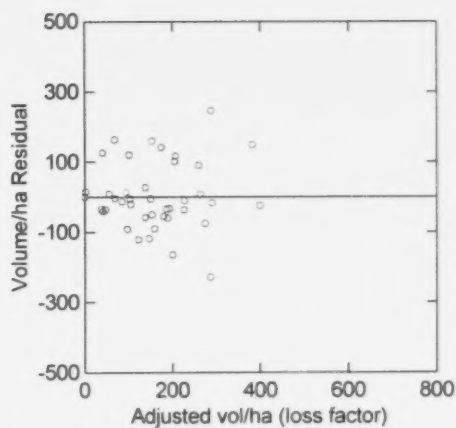


Fig. 26: *Lodgepole pine*
Residuals for ratio-adjusted volume.

RESIDUALS PLOTS FOR RATIO-ADJUSTED VOLUME (loss factor)

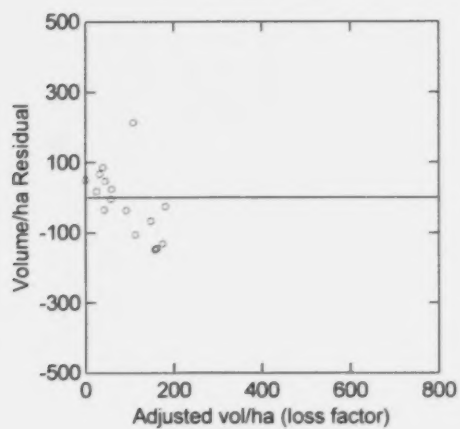


Fig. 27: Drybelt fir
Residuals for ratio-
adjusted volume.

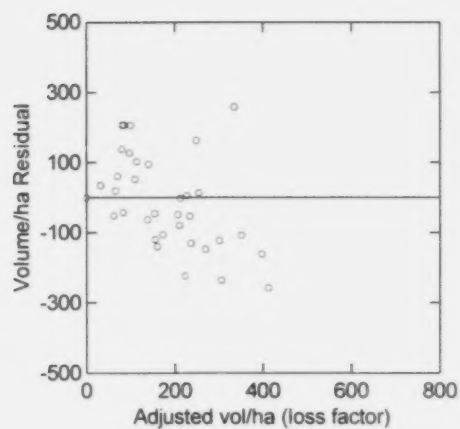


Fig. 28: Wetbelt fir
Residuals for ratio-
adjusted volume.

A-12 Sample size and sampling error

Sample Size Estimates for Lillooet TSA (all VT samples)

NOTE: CV is from VRI Ratio-of-Means (ground volume/unadjusted inventory volume)

at "TSR" utilization, net dwb (n=128, all VT samples)

where $n = t^2 \cdot CV^2 / PE^2$ (t at $\alpha/2$, n-1)

CV from all VT samples

Sample size for a given CV and PE:

CV= 77.5%
alpha= 0.05

Error % PE	Sample size n
10%	233
15%	105

CV= 77.5%
alpha= 0.1

Error % PE	Sample size n
10%	164
15%	74

Sample size for a given CV and n:

CV= 77.5%
alpha= 0.05

Sample size n	Error % PE
50	22.0%
86	16.6%
100	15.4%
120	14.0%
130	13.4%
150	12.5%
175	11.6%
200	10.8%
225	10.2%

CV= 77.5%
alpha= 0.1

Sample size n	Error % PE
50	18.4%
86	13.9%
100	12.9%
120	11.7%
130	11.3%
150	10.5%
175	9.7%
200	9.1%
225	8.5%

Note: EXCEL function for tinv provides a t-value of the 'half interval' for a specified alpha
Sample size formula is not 'automatic'; degrees of freedom for t-value must be iterated

Sample Size Estimates for Lillooet TSA ("Operable")

NOTE: CV is from VRI Ratio-of-Means (ground volume/unadjusted inventory volume)
at "TSR" utilization, net dwb (n=71, operable i.e. timber harvesting landbase)

where $n = t^2 \cdot CV^2 / PE^2$ (t at $\alpha/2$, n-1)

CV for "timber harvesting landbase"

Sample size for a given CV and PE:

CV= 68.8%
 alpha= 0.05

Error % PE	Sample size n
10%	184
15%	83

CV= 68.8%
 alpha= 0.1

Error % PE	Sample size n
10%	130
15%	59

Sample size for a given CV and n:

CV= 68.8%
 alpha= 0.05

Sample size n	Error % PE
50	19.6%
86	14.8%
100	13.7%
120	12.4%
130	11.9%
150	11.1%
175	10.3%
200	9.6%
225	9.0%

CV= 68.8%
 alpha= 0.1

Sample size n	Error % PE
50	16.3%
86	12.3%
100	11.4%
120	10.4%
130	10.0%
150	9.3%
175	8.6%
200	8.0%
225	7.6%

Note: EXCEL function for tinv provides a t-value of the 'half interval' for a specified alpha
 Sample size formula is not 'automatic'; degrees of freedom for t-value must be iterated.

Lillooet Forest District

Documentation of Analysis for Vegetation Resources Inventory Statistical Adjustment

ADDENDUM II

**PREPARED BY:
MINISTRY OF SUSTAINABLE FORESTS AND RANGE
FOREST ANALYSIS AND INVENTORY BRANCH**

NOVEMBER 2005

Background:

In the summer of 2004, it was determined that the Lillooet TSA Vegetation Resource Inventory unadjusted attribute files were assigned incorrect stocking class source code values in some cases. As a result, volumes calculated using this information was incorrect.

VRI analysis procedures compare ground sample volumes to those calculated in the attribute files. Volume adjustment ratios are calculated to adjust for the difference between the sample data and the attribute data. The volume adjustment factors identified in the previous addendum (April 2003) were correct for the volumes that were in those attribute files, and therefore the adjusted volumes were also correct.

Having identified the problems with the stocking class source code on the attribute files, however, it was felt it was necessary to correct these attributes, recalculate the attribute volumes, and then recalculate new volume adjustment factors to adjust the attribute volumes.

Improvements Made to the Analysis:

A 'stocking class fix' was applied to all attribute data in the Lillooet TSA. A comparison of the ground sample data to the new attribute data resulted in new volume adjustment factors.

The resulting changes to the volume adjustment factors can be seen in the table below. Of most significance are the changes to the impact ratios, which is most pronounced in the Pine leading strata.

The following table identifies new volume adjustment factors.

Lillooet VRI Adjustment Ratios: July 14/04

Mean vol/ha and ratios (typeid=6 excluded). 17.5cm+ dbh net dwb util except Pl,Pa,Decid at 12.5cm+ dbh net dwb
TYPEID 6 SAMPLES EXCLUDED FOR VOLUME ADJUSTMENT

			Mean NEW Attribute- adjusted Inventory vol/ha	NEW Volume Adjustment Ratio	Mean grd NVAF vol/ha	Mean NEW unadjusted Inventory vol/ha	NEW Impact Ratio	Mean grd NVAF vol/ha	Mean OLD unadjusted Inventory vol/ha	OLD Impact Ratio (do not use)
THLB >30 years										
SBDEC		15	351.353	1.603	351.353	246.107	1.428	351.353	246.187	1.427
PINE	<=100	10	116.618	0.843	116.618	91.45	1.275	116.618	85.93	1.357
	>100	29	194.549	1.296	194.549	171.962	1.131	194.549	167.966	1.158
WET FD	<=140	12	172.385	1.190	172.385	129.117	1.335	172.385	129.267	1.334
	>140	17	140.56	1.303	140.56	178.735	0.786	140.56	176.459	0.797
DRY FD		13	87.78	1.860	87.78	109.992	0.798	87.78	107.862	0.814
NON-THLB >30 yrs										
All inoperable		21	265.045	1.359	265.045	179.067	1.480	265.045	179.457	1.477
SBDEC	OPER	13	314.021	1.527	314.021	210.523	1.492	314.021	210.085	1.495
PINE	OPER	12	165.701	1.196	165.701	140.242	1.182	165.701	131.65	1.259
WET/DRY FD	OPER	18	149.454	1.415	149.454	105.233	1.420	149.454	105.339	1.419

NEW Volume Adjustment Ratio

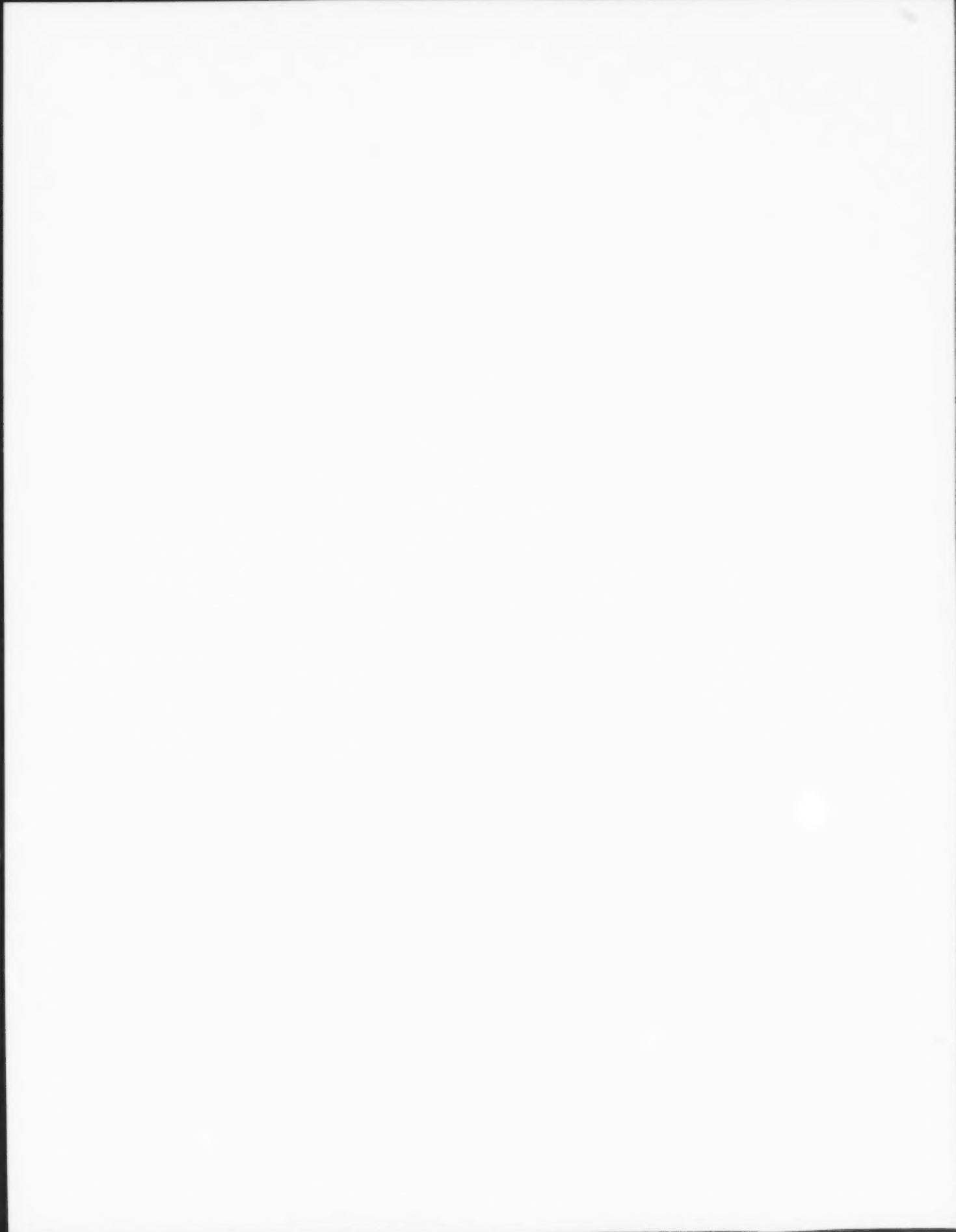
Age and Height Ratios remained unchanged - the volume adjustment ratios changed significantly from the previous analysis. Note that the Impact Ratios better describe the changes in the impact the adjustments have on the polygon volumes.

Mean NEW unadjusted Inventory vol/ha

Changes in Projected Stocking Class values resulted in slight changes to the inventory volumes

NEW Impact Ratio

By comparing the OLD and NEW impact ratios one can see the results of changes made to the volume adjustment ratios (as a result of changes made to the unadjusted inventory).



Lillooet Forest District

Documentation of Analysis for Vegetation Resources Inventory Statistical Adjustment

ADDENDUM

PREPARED BY:
MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
RESOURCES INVENTORY DEPARTMENT
TERRESTRIAL INFORMATION BRANCH

APRIL 2003



1. BACKGROUND

In the 1998/99 field seasons 128 timber emphasis plots were established in the vegetated treed portion of the Lillooet Forest District as part of the Vegetation Resources Inventory (VRI) implementation. This data was analyzed in the spring of 2000 and preliminary adjustment factors (age, height and volume¹) were provided. This analysis was documented in the report "Lillooet Forest District: Documentation of Vegetation Resources Inventory Preliminary Analysis" available on the Ministry of Sustainable Resource Management (MSRM) website².

An additional 18 samples were established in the 2000 field season. After reviewing the data and the project objectives, stakeholders decided to establish more samples and to focus sampling efforts in the operable forest landbase³. Hence in the 2001 field season, a further 40 samples were established in the operable areas in the district. As a result of oversampling in the operable forest landbase, weights must be computed and applied in any analysis of this VRI data.

NVAF sampling was also completed and new NVAF values were computed for the Lillooet Forest District. The new NVAF values were based on a total sample size of 108 live trees and 7 dead trees.

This addendum provides results based on the completed NVAF and all 186 VRI samples in the Lillooet Forest District.

2. DATA AND ANALYSIS

2.1 Population of interest

The initial population of interest for this analysis was the vegetated treed landbase in the Lillooet Forest District. However, the MSRM is currently investigating policy around adjustments to very young stands. Due to the uncertainty surrounding adjustments for young stands, adjustment factors fit for the population greater than 30 years of age were recommended. Hence the population of interest for this analysis was changed to reflect this recommendation and was redefined as all vegetated treed polygons greater than 30 years of age in the Lillooet Forest District⁴.

2.2 Post-Stratification

This analysis was intended to support the upcoming timber supply analysis in this TSA. Hence, the basic unit of stratification identified by the stakeholders was "timber harvesting landbase" (THLB) and "non-timber harvesting landbase" (non-THLB). Within this basic unit of stratification, species stratification was similar to that defined in the preliminary analysis:

- Spruce, balsam or deciduous leading
- Lodgepole pine leading

¹ Volume adjustment factors were based on compiled volumes that were based on loss factors and net factoring with NVAF. The NVAF sampling was incomplete hence all results were preliminary.

² Please refer to this report for further background and a full description of the analysis methodology.

³ Note that the operable forest landbase did not correspond with the "timber harvesting landbase" (THLB). All samples within the THLB were operable however the non-THLB area included a mix of operable and inoperable samples.

⁴ A total of 10 samples (all in the THLB) were less than or equal to 30 years of age.

- Douglas-fir leading in the dry belt⁵
- Douglas-fir leading in the wet belt⁶

In addition, age sub-stratification was also investigated in this analysis. Based on this analysis, the lodgepole pine stratum in the THLB was post-stratified into two age groups: ≤ 100 years and > 100 years. Similarly, the THLB Douglas-fir leading in the wet belt was also post-stratified into two age groups: ≤ 140 years and > 140 years.

2.3 Weighting

Since the operable portion of the landbase was oversampled, weights were required to compute overall statistics in this unit and strata statistics if a stratum included a mix of operable and inoperable samples. Areas used to compute the weights⁷ are shown in Appendix B.

2.4 Data source

2.4.1 Inventory data

Inventory attribute data was obtained from the file "Lillooet_VRI&SUB.xls"⁸. This file was also the source of the operability information. Nine of the original samples could not be located in the originally selected polygons and were replaced⁹.

The inventory data was projected to the year of ground sampling¹⁰. The year of ground sampling was determined from the file "vri_gps-Lillooet.xls". The status of each sample with respect to inclusion/exclusion in the THLB was provided in the file "smp_data.txt" provided on February 6, 2003 and additional information regarding minor changes to this THLB assignment were provided by Lloyd Wilson¹¹. Data on operability provided in file "LILLOOET VRI&SUB.xls" provided January 4, 2003. Note that for computation of the sample selection weights, operability was fixed as of the time of sample selection.

2.4.2 Compiled data

The compiled data for the Lillooet VRI was provided on April 2, 2003. This compilation included BEC-based taper, and the NVAF values based on the completed NVAF sampling of a total of 108 live trees and 7 dead trees. A summary of the 2003 NVAF results is shown in Appendix A.

⁵ Dry belt Douglas-fir is defined as Douglas-fir leading occurring in IDF-xh-1, IDF-xh-2, IDFdk2b, PP or BG biogeoclimatic zones and also all Py leading.

⁶ Wet belt Douglas-fir is defined as all Douglas-fir leading polygons not in the drybelt.

⁷ Areas were provided by Lloyd Wilson.

⁸ Inventory data for the sample 230 which was on mapsheet 092J029 was not available and was provided by Gary Johansen in a separate file "092J029.xls".

⁹ The nine replacement samples were: sample #'s 61, 62, 67, 88, 105, 109, 116, 127, and 249. Inventory data for the replacement samples were provided in the files "9_repl.xls" and "9_operab.xls".

¹⁰ Height was projected using SiteTools.

¹¹ Four samples in the Spruce Lake area changed from THLB to non-THLB. Note that the operability of these samples was not changed. Operability remained the same as it was defined at the time of sample selection. This is critical to being able to compute sample selection weights since the weighting is based on operability.

3. RESULTS AND DISCUSSION

3.1 Height and age adjustment factors

Height and age adjustment factors¹² were computed using the THLB/non-THLB as the basic unit of stratification. As can be seen in Tables 1 and 2 below, the species and age sub-stratification differed slightly between the THLB and non-THLB. In the non-THLB, all inoperable samples comprise a single sub-stratum. Operable samples in the non-THLB were sub-stratified by leading species. Note that "operability" is defined as of the time of sample selection.

Tables 1 and 2 show the ratio-of-means age adjustment factors for the THLB and non-THLB respectively. In general, inventory ages in the Lillooet TSA were generally overestimated (often by more than 20%) except for younger pine and younger wetbelt fir stands where ages were underestimated.

Table 1: Mean ages and ratio adjustment factors for age; Lillooet TSA, THLB, VT, >30 years.

Stratum	Age Adjustment for THLB, VT, >30 years			
	n	Mean ground age	Mean inventory age	Ratio
Spruce, balsam, deciduous	13	139.51	198.923	0.701
Pine	9	86.066	72.444	1.188
	29	128.659	144.759	0.889
Wetbelt fir	11	132.065	114.455	1.154
	16	132.876	188	0.707
Drybelt fir	11	162.696	191.182	0.851

Table 2: Mean ages and ratio adjustment factors for age; Lillooet TSA, non-THLB, VT, >30 yrs.

Stratum	Age Adjustment for non-THLB, VT, >30 yrs			
	n	Mean ground age	Mean inventory age	Ratio
All inoperable	31	129.429	182.129	0.711
Spruce, balsam, decid; operable	13	203.084	213.846	0.950
Pine operable	13	138.710	129.769	1.069
Wet & Dry belt fir operable	19	142.398	183.842	0.775

The ratio-of-means adjustment factors for height for the THLB and non-THLB are shown in Tables 3 and 4. Heights were generally overestimated in the THLB fir strata, although for younger fir stands in the wetbelt, heights were slightly underestimated. In THLB pine leading stands, heights were underestimated for younger stands and slightly overestimated in older stands. This was consistent with trends in pine in other units. In the non-THLB, height bias was generally small.

¹² All adjustment factors were computed using current MSRM standards.

Table 3: Mean heights and ratio adjustment factors for height; Lillooet TSA, THLB, VT, >30 years.

Stratum	Height Adjustment for THLB, VT, >30 years			
	n	Mean ground height (m)	Mean inventory height (m)	Ratio
Spruce, balsam, deciduous	13	22.9	24.254	0.944
Pine <=100 yrs	10	16.224	14.41	1.126
> 100 yrs	29	17.234	17.897	0.963
Wetbelt fir <=140 yrs	12	21.293	20.358	1.046
>140 yrs	16	19.566	24.55	0.797
Drybelt fir	10	15.193	20.88	0.728

Table 4: Mean heights and ratio adjustment factors for height; Lillooet TSA, non-THLB, VT, >30 years.

Stratum	Height Adjustment for non-THLB, VT, >30 yrs			
	n	Mean ground height (m)	Mean inventory height (m)	Ratio
All inoperable	31	20.244	19.197	1.055
Spruce, balsam, decid; operable	13	21.714	22.031	0.986
Pine operable	13	16.611	16.254	1.022
Wet & Dry belt fir operable	18	19.587	19.411	1.009

3.2 Volume adjustment factors

In the derivation of the volume adjustment factors, the compiled volumes were based on net factoring with the NVAF applied. Volume utilization for ground and inventory volumes was 17.5cm+ dbh net dwb for all leading species except 12.5cm+ dbh net dwb for Pine (except Py) and deciduous leading¹³.

Volume adjustment factors were based on ratio-of-means. As per the current MSRM standard, the ratio was computed as the mean ground compiled volume over the mean "attribute-adjusted" inventory volume (i.e. the inventory volume¹⁴ based on adjusted height and age). The volume adjustment factors for the THLB and non-THLB are shown in Tables 5 and 6.

¹³ The utilization was determined by the inventory leading species.

¹⁴ All inventory volumes were obtained from VDYP v6.6d.

Table 5: Mean volumes and ratio adjustment factors for "attribute-adjusted" inventory volume/ha; Lillooet TSA, THLB, VT, >30 years.

Stratum	Volume Adjustment for THLB, VT, >30 years			
	n	Mean NVAF vol/ha	Mean attribute-adj'd inventory vol/ha	Ratio
Spruce, balsam, deciduous	15	351.353	223.02	1.575
Pine <=100 yrs	10	116.618	119.1	0.979
> 100 yrs	29	194.549	146.403	1.329
Wetbelt fir <=140 yrs	12	172.385	144.792	1.191
>140 yrs	17	140.56	110.288	1.274
Drybelt fir	13	87.78	48.777	1.800

Table 6: Mean volumes and ratio adjustment factors for "attribute-adjusted" inventory volume/ha; Lillooet TSA, non-THLB, VT, >30 years.

Stratum	Volume Adjustment for non-THLB, VT, >30 yrs			
	n	Mean NVAF vol/ha	Mean attribute-adj'd inventory vol/ha	Ratio
All inoperable	35	210.528	141.623	1.487
Spruce, balsam, decid; operable	13	314.021	206.246	1.523
Pine operable	13	160.473	141.138	1.137
Wet & Dry belt fir operable	19	146.894	103.626	1.418

3.3 Volume impact and sampling error

The volume factors in Tables 5 and 6 represent adjustments to volumes based on inventory heights and ages that have already been adjusted (i.e. "attribute-adjusted" inventory volumes). To determine the overall volume impact of the set of adjustments (age, height and volume), the ground volumes were compared with the unadjusted inventory volumes (i.e. inventory volumes prior to any age or height adjustment). These volume impact ratios are shown in Table 7 and 8 by stratum and overall for each of the THLB and non-THLB for the VT, >30 years population of interest.

This analysis indicated that volume in the THLB was underestimated by about 13%. In the non-THLB, volumes were underestimated by nearly 50%. Much of this underestimation appears to be associated with the VDYP volume estimation. These results are supported by similar findings for the Inventory Audit completed in 1995 which suggested that volumes in this unit were underestimated by about 20%. The Audit also suggested that the majority of the inventory volume bias was associated with the VDYP model whereas the attributes (height and age) accounted for a much smaller component of the bias.

Sampling error (at the 95% probability level) is also shown by stratum and overall. In the THLB, a sampling error of 9.9% was achieved. In the non-THLB, the overall sampling error was 18.0%.

Table 7: Sampling error and adjustment impact (height, age and volume) on unadjusted inventory volume/ha; Lillooet TSA, THLB, VT, >30 years.

Stratum	Volume "Impact" for THLB, VT, >30 years				
	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio	Sampling Error % at 95%
Spruce, balsam, decid.	15	351.353	246.187	1.427	20.4%
Pine <=100 yrs	10	116.618	85.93	1.357	36.8%
> 100 yrs	29	194.549	167.966	1.158	18.7%
Wetbelt fir <=140 yrs	12	172.385	129.267	1.334	31.1%
>140 yrs	17	140.56	176.459	0.797	24.1%
Drybelt fir	13	87.78	107.862	0.814	50.3%
Overall				1.126	9.9%

Table 8: Sampling error and adjustment impact (height, age and volume) on unadjusted inventory volume/ha; Lillooet TSA, non-THLB, VT, >30 years.

Stratum	Volume "Impact" for non-THLB, VT, >30 yrs				
	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio	Sampling Error % at 95%
All inoperable	35	210.528	130.374	1.615	25.3%
Spruce, balsam, decid; operable	13	314.021	210.085	1.495	46.9%
Pine operable	13	160.473	134.077	1.197	35.2%
Wet & Dry belt fir operable	19	146.894	101.6	1.446	50.7%
Overall				1.510	18.0%

4. APPENDIX A: SUMMARY OF NVAF RESULTS

(L)ive (D)ead	Operability Group	Species Group	No of Sample Trees	NVAF for VRI Net Merch Volumes**	VRI Net Merch Vol % Sample Error ***	NVAF based on Gross Merch Volumes - BEC Taper	Gross Vol % Sample Error	NVAF Based on FIZ Taper and 1976 Loss Decay and Waste Net Merch Volume	FIZ Taper and 1976 Loss Factor net Merch Vol % Sample Error
D			7	1.039	12.9	1.05	12.5	1.77	14.0
L	Op	Flr	33	1.072	5.8	1.09	4.9	1.09	5.3
L	Op	Pl	28	1.041	6.8	1.05	6.9	1.08	5.8
L	Op	S&B	28	1.018	4.7	1.03	4.9	1.07	4.1
L	Op	Rest*	6	0.873	15.7	0.93	13.9	1.08	7.1
L	Inop	All	13	1.027	8.7	1.07	7.7	1.08	10.1
L	All	Ac	2	0.803		0.88		1.12	
L	All	B	15	1.012	6.8	1.01	7.4	1.08	6.0
L	All	Cw	2	1.041		1.11		1.11	
L	All	Fd	44	1.058	5.8	1.07	5.4	1.07	5.4
L	All	Pa	2	1.084		1.09		0.98	
L	All	Pl	28	1.041	6.8	1.05	6.9	1.08	5.8
L	All	Py	2	1.165		1.16		1.03	
L	All	S	13	1.026	7.0	1.06	5.6	1.05	6.2

NOTES:

- * Rest stratum is composed of all species excepting Fd, Pl, S and B.
- ** Net merch volumes are based on the BEC taper equation and exclude decay and waste volumes.
- **Bolded values are the NVAF adjustments applied to the VRI ground sample volumes.**
- MoF Research Br Design Based Weighting Method
- Sampling error is based on 95% probability

5. APPENDIX B: DETAILED ANALYSIS RESULTS FOR ALTERNATIVE STRATIFICATION

Table 1: Lillooet TSA, THLB, VT, 0+ years

Stratum	AGE				Height			
	n	Mean grd	Mean inv	Ratio	n	Mean grd	Mean inv	Ratio
SBDEC	15	124.08	174.133	0.713	15	20.237	21.207	0.954
	42	109.161	116.595	0.936	43	15.807	15.63	1.011
WET FD	29	125.392	148.414	0.845	30	19.485	21.45	0.908
DRY FD	11	162.696	191.182	0.851	10	15.193	20.88	0.728

Table 2: Lillooet TSA, THLB, VT, >30 years

Stratum	AGE				Height			
	n	Mean grd	Mean inv	Ratio	n	Mean grd	Mean inv	Ratio
SBDEC	13	139.51	198.923	0.701	13	22.9	24.254	0.944
PINE	38	118.571	127.632	0.929	39	16.975	17.003	0.998
WET FD	27	132.545	158.037	0.839	28	20.306	22.754	0.892
DRY FD	11	162.696	191.182	0.851	10	15.193	20.88	0.728

Table 3: Lillooet TSA, THLB, VT, >30 years, age breaks for PINE and FIR strata

Stratum	AGE				Height	
	n	Mean grd	Mean inv	Ratio	n	Mean inv
SBDEC	13	139.51	198.923	0.701	13	22.9
PINE	9	86.066	72.444	1.188	10	16.224
	29	128.659	144.759	0.889	29	17.234
WET FD	11	132.065	114.455	1.154	12	21.293
	16	132.876	188	0.707	16	19.566
DRY FD	3	172.258	111.667	1.543	3	19.181
	8	159.111	221	0.720	7	13.483
						21.2
						0.636

Table 4: Lillooet TSA, THLB, VT, >30 years

Stratum	Area (ha)	Volume Adjustment				Volume Impact			
		n	Mean NVAF vol/ha	Mean attribute-adj'd inventory vol/ha	Ratio	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio
SBDEC	38943.31	15	351.353	223.02	1.575	15	351.353	246.187	1.427
PINE	103986.1	39	174.567	144.826	1.205	39	174.567	146.931	1.188
WET FD	95997.99	29	153.729	122.234	1.258	29	153.729	156.931	0.980
DRY FD	35055.92	13	87.78	48.777	1.800	13	87.78	107.862	0.814

OVERALL IMPACT RATIO AND 95% SAMPLING ERROR for THLB, VT, >30 yrs: $1.136 \pm 10.3\%$

Table 5: Lillooet TSA, THLB, VT, >30 years, age breaks for PINE and FIR strata

Stratum	Volume Adjustment				Volume Impact			
	n	Mean NVAF vol/ha	Mean attribute-adj'd inventory vol/ha	Ratio	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio
SBDEC	15	351.353	223.02	1.575	15	351.353	246.187	1.427
PINE	10	116.618	119.1	0.979	10	116.618	85.93	1.357
	29	194.549	146.403	1.329	29	194.549	167.966	1.158
WET FD	12	172.385	144.792	1.191	12	172.385	129.267	1.334
	17	140.56	110.288	1.274	17	140.56	176.459	0.797
DRY FD	3	84.104	111.7	0.753	3	84.104	117.633	0.715
	10	88.882	30.35	2.929	10	88.882	104.93	0.847

Table 6: Lillooet TSA, non-THLB, VT, 0+ years¹⁵

Stratum	Area	AGE			Height		
		n	Mean	inv	n	Mean	inv
SBDEC	OPER	13	203.084	213.846	13	21.714	22.031
	INOP	11	133.302	194.545	10	18.918	20.24
PINE	OPER	13	138.71	129.769	13	16.611	16.254
	INOP	5	107.85	154	5	16.215	12.9
WET FD	OPER	9	143.374	185.778	9	24.078	22.256
	INOP	12	120.096	184.25	12	23.973	21.975
DRY FD	OPER	10	141.521	182.1	9	15.096	16.567
	INOP	3	188.532	175	3	16.467	15.1
							0.975

¹⁵ Note: there were no non-THLB samples ≤ 30 years. If the >30 years criterion is applies in this stratum, the mean values do not change however, the ratios change slightly due to new areas for weighting.

Table 7: Lillooet TSA, non-THLB, VT, 30+ years¹⁶

Stratum	Area	AGE			Height		
		n	Mean	inv	n	Mean	Ratio
SBDEC	OPER	13	203.084	213.846	13	21.714	0.957
	INOP	11	133.302	194.545	10	18.918	0.800
PINE	OPER	13	138.71	129.769	13	16.611	1.127
	INOP	5	107.85	154	5	16.215	12.9
WET FD	OPER	9	143.374	185.778	9	24.078	1.087
	INOP	12	120.096	184.25	12	23.973	21.975
DRY FD	OPER	10	141.521	182.1	9	15.096	16.567
	INOP	3	188.532	175	3	16.467	15.1

Table 8: Lillooet TSA, non-THLB, VT, 30+ years, ALTERNATE STRATIFICATION

Stratum	Area	AGE			Height		
		n	Mean	inv	n	Mean	Ratio
All inoperable	183060.2	31	129.429	182.129	31	20.244	1.055
SBDEC	51791.55	13	203.084	213.846	13	21.714	0.986
PINE	44880.29	13	138.71	129.769	13	16.611	1.022
WET/DRY FD	68034.78	19	142.398	183.842	18	19.587	1.009

¹⁶ Note: there were no non-THLB samples ≤ 30 years. If the >30 years criterion is applies in this stratum, the mean values do not change however, the ratios change slightly due to new areas for weighting.

Table 9: Lillooet TSA, non-THLB, VT, >30 years

Stratum	Area	Volume Adjustment				Volume Impact			
		n	Mean NVAF vol/ha	Mean attribute- adj'd inventory vol/ha	Ratio	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio
SBDEC	OPER	13	314.021	196.623	1.623	13	314.021	210.085	1.522
	INOP	14	235.882	143.15		14	235.882	152.279	
PINE	OPER	13	160.473	161.069	0.970	13	160.473	134.077	1.192
	INOP	6	98.774	106.1		6	98.774	83.383	
WET FD	OPER	9	224.349	175.778	1.403	9	224.349	154.089	1.630
	INOP	12	271.192	181.042		12	271.192	153.642	
DRY FD	OPER	10	77.184	51.35	1.795	10	77.184	54.36	1.686
	INOP	3	73.067	26.8		3	73.067	29.067	

Table 10: Lillooet TSA, non-THLB, VT, >30 years, ALTERNATE STRATIFICATION

Stratum	Area	Volume Adjustment				Volume Impact			
		n	Mean NVAF vol/ha	Mean attribute- adj'd inventory vol/ha	Ratio	n	Mean NVAF vol/ha	Mean unadjusted inventory vol/ha	Ratio
All inoperable	183060.2	35	210.528	141.623	1.487	35	210.528	130.374	1.615
SBDEC	operable 51791.55	13	314.021	206.246	1.523	13	314.021	210.085	1.495
PINE	operable 44880.29	13	160.473	141.138	1.137	13	160.473	134.077	1.197
WET/DRY FD	operable 68034.78	19	146.894	103.626	1.418	19	146.894	101.6	1.446

OVERALL IMPACT RATIO AND 95% SAMPLING ERROR: $1.510 \pm 18\%$

6. APPENDIX C: SCATTERPLOTS: THLB, >30 YEARS

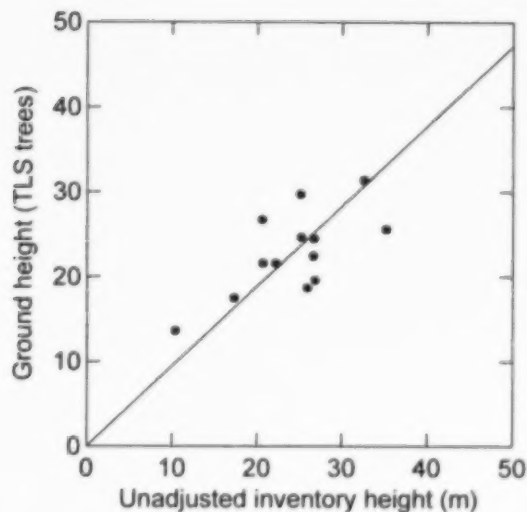


Fig. 1: SB, Dec leading. Ground and inventory height relationship. Line corresponds to ratio of means.

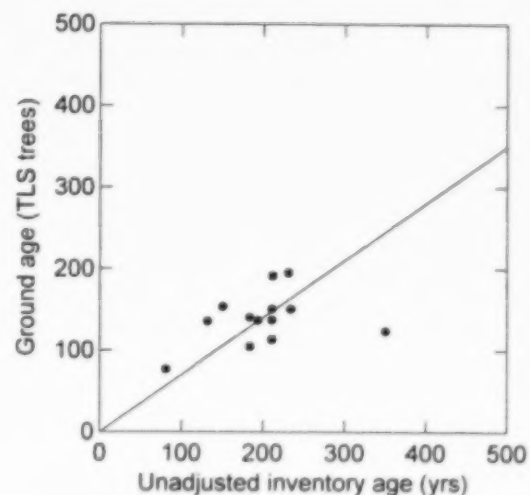


Fig. 2: SB, Dec leading. Ground and inventory age relationship. Line corresponds to ratio of means.

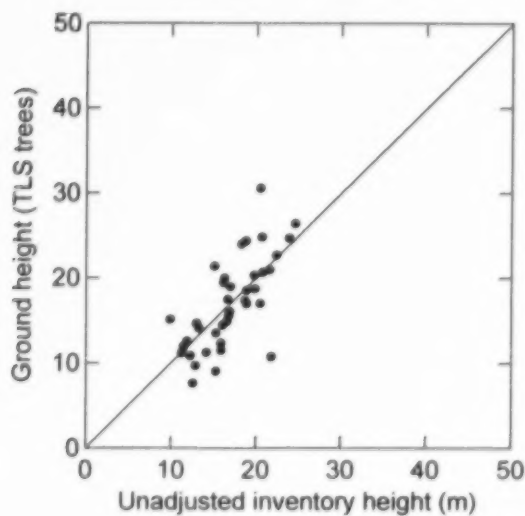


Fig. 3: Pl, Pa leading. Ground and inventory height relationship. Line corresponds to ratio of means.

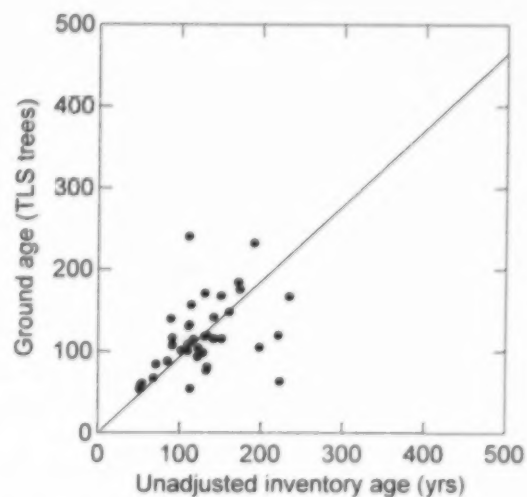


Fig. 4: Pl, Pa leading. Ground and inventory height relationship. Line corresponds to ratio of means.

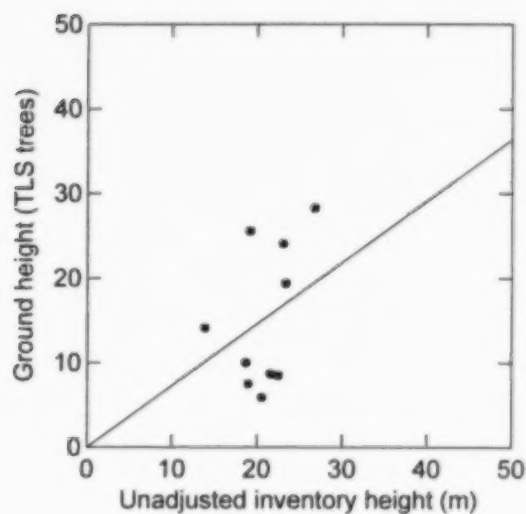


Fig. 5: Dry belt fir. Ground and inventory height relationship. Line corresponds to ratio of means.

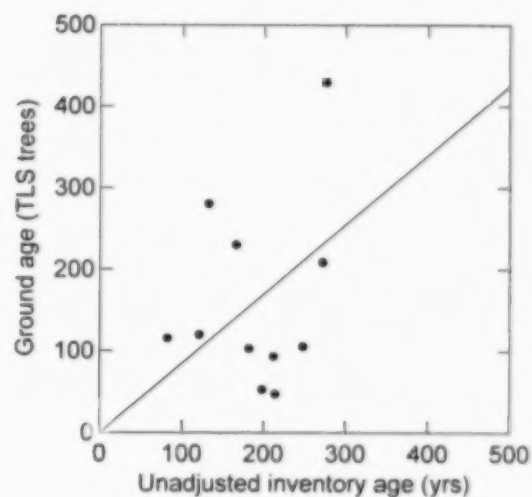


Fig. 6: Dry belt fir. Ground and inventory age relationship. Line corresponds to ratio of means.

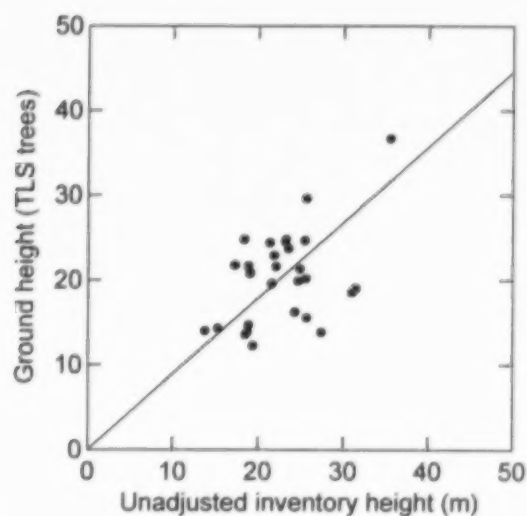


Fig. 7: Wet belt fir. Ground and inventory height relationship. Line corresponds to ratio of means.

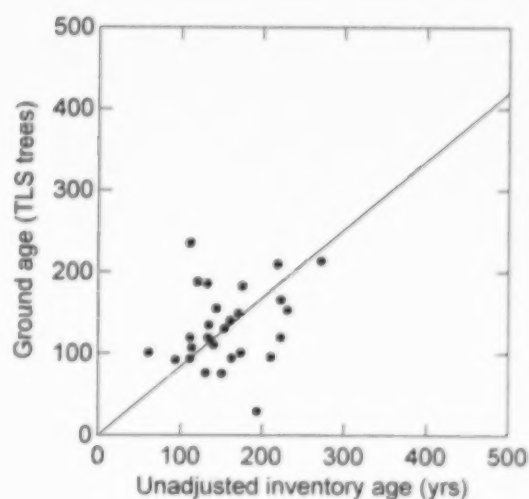


Fig. 8: Wet belt fir. Ground and inventory age relationship. Line corresponds to ratio of means.

Age and height residuals: THLB, >30 years

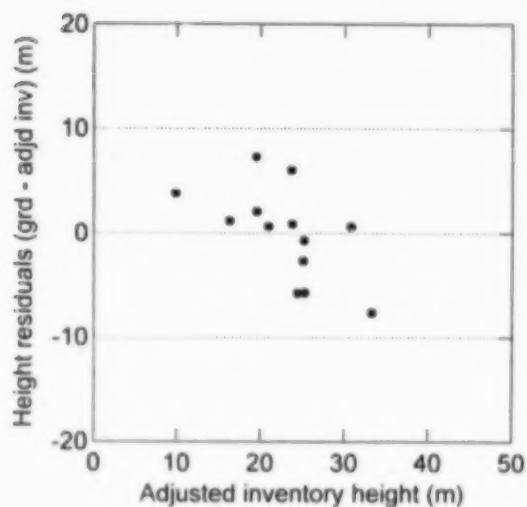


Fig. 9: SB, Dec leading. Height residuals vs adjusted inventory height.

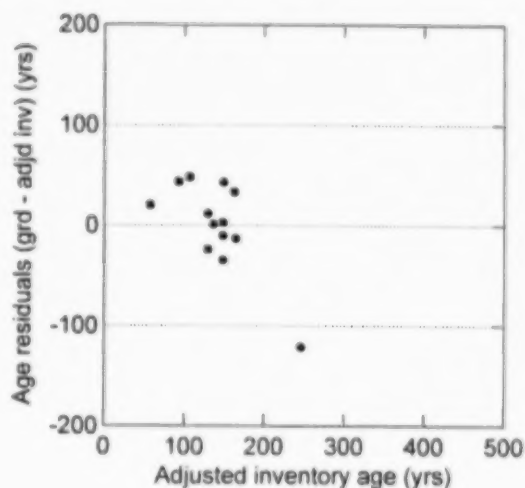


Fig. 10: SB, Dec leading. Age residuals vs adjusted inventory age.

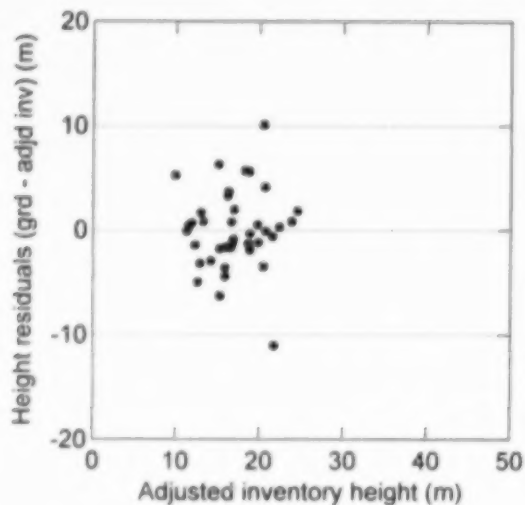


Fig. 11: Pl, Pa leading. Height residuals vs adjusted inventory height.

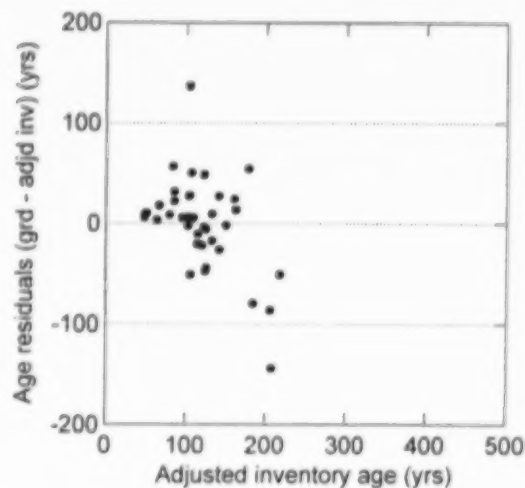


Fig. 12: Pl, Pa leading. Age residuals vs adjusted inventory age.

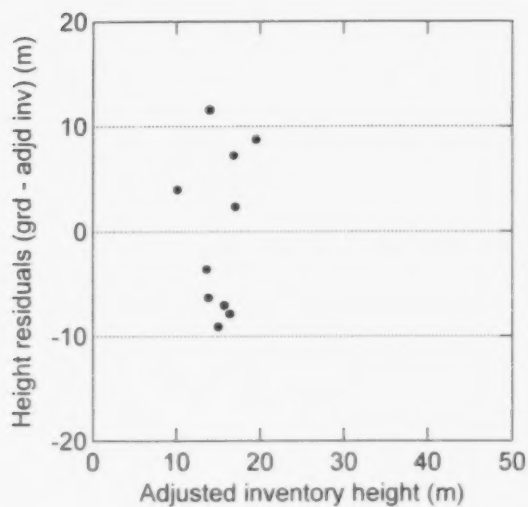


Fig. 13: Dry belt fir. Height residuals vs adjusted inventory height.

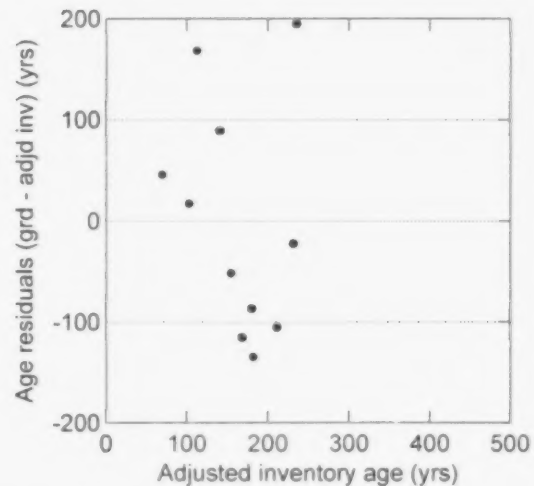


Fig. 14: Dry belt fir. Age residuals vs adjusted inventory age.

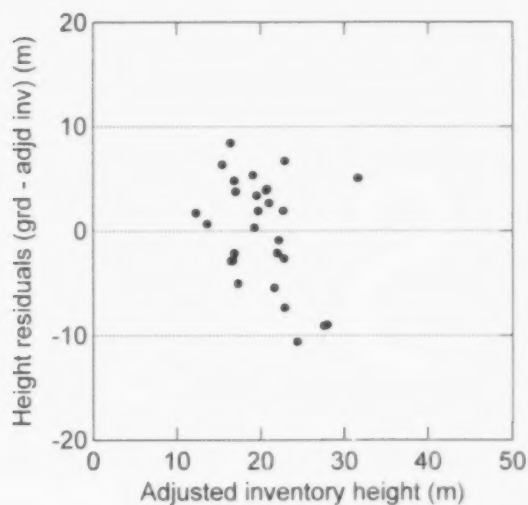


Fig. 15: Wet belt fir. Height residuals vs adjusted inventory height.

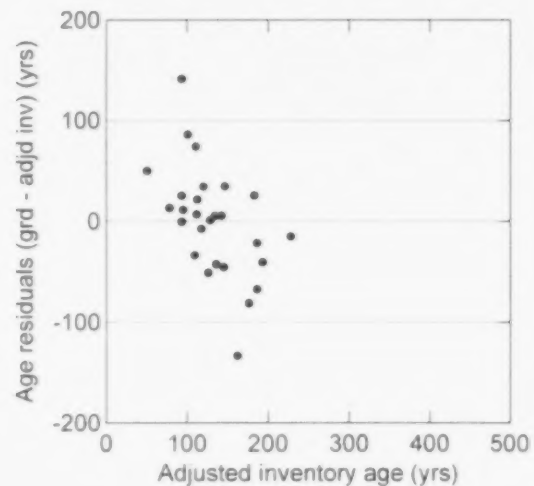


Fig. 16: Wet belt fir. Age residuals vs adjusted inventory age.

Volume relationships and residuals: THLB, >30 years

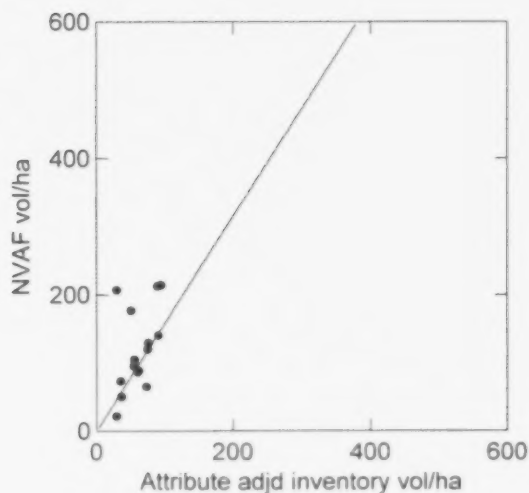


Fig. 17: SB, Dec leading. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

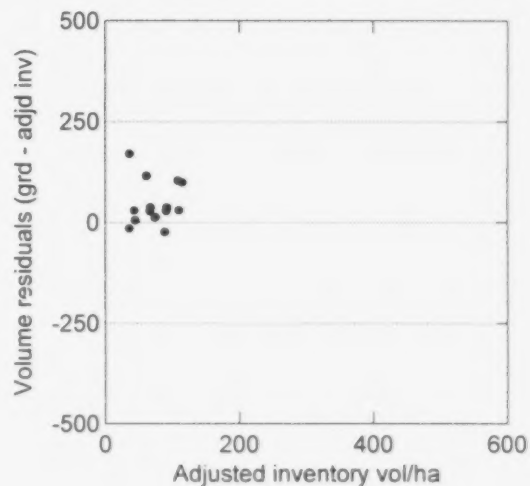


Fig. 18: SB, Dec leading. Volume residuals vs adjusted inventory volume.

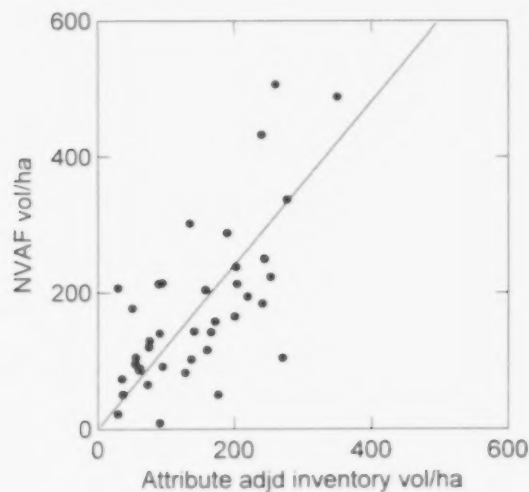


Fig. 19: PI, Pa leading. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

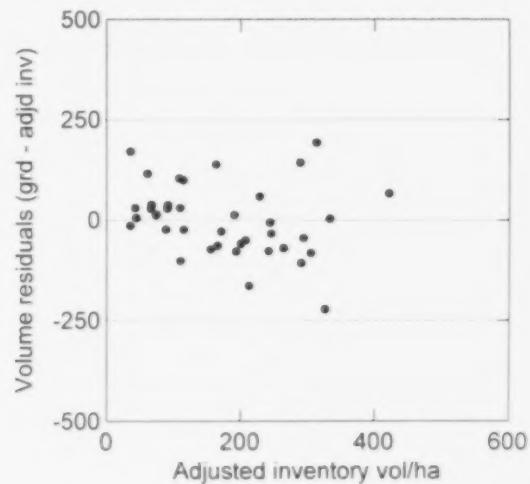


Fig. 20: PI, Pa leading. Volume residuals vs adjusted inventory volume.

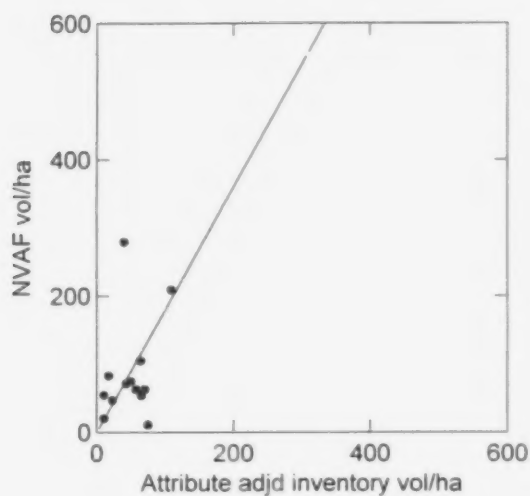


Fig. 21: Dry belt fir. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

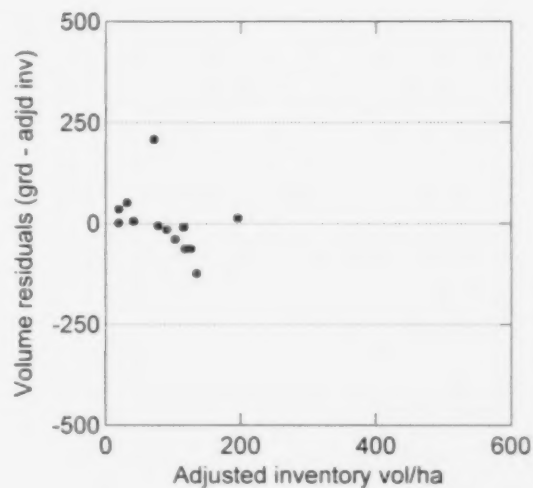


Fig. 22: Dry belt fir. Volume residuals vs adjusted inventory volume.

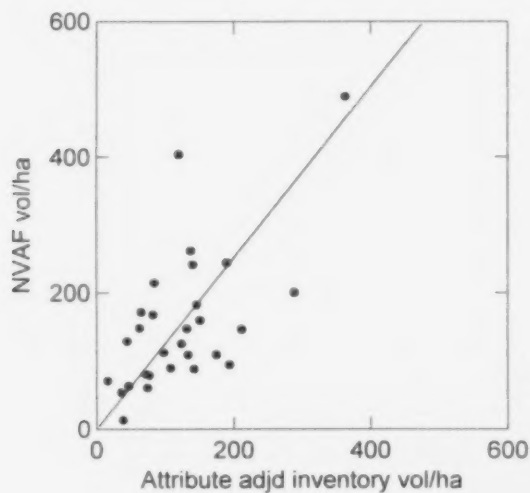


Fig. 23: Wet belt fir. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

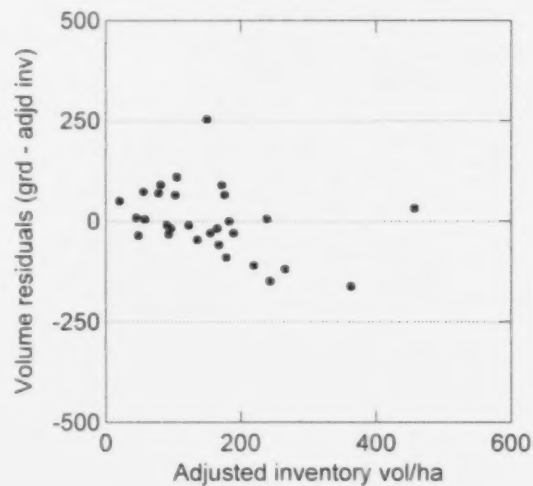


Fig. 24: Wet belt fir. Volume residuals vs adjusted inventory volume.

Height and volume residuals vs. inventory age: THLB, >30 years

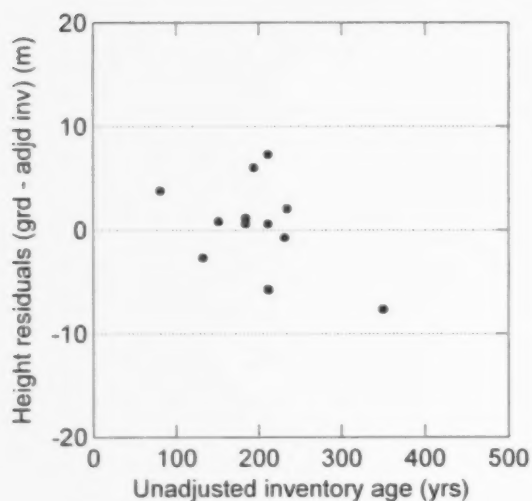


Fig. 25: SB,Dec leading. Height residuals versus unadjusted inventory age.

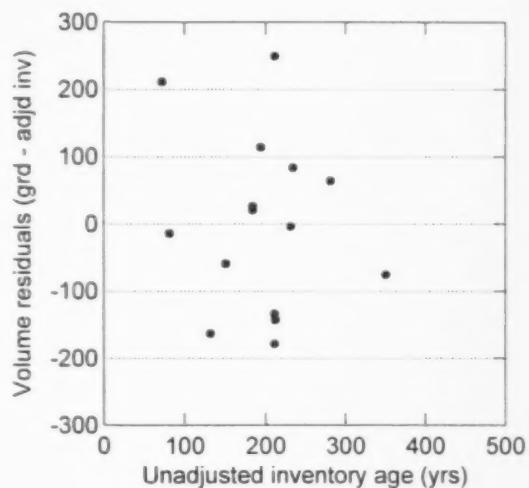


Fig. 26: SB,Dec leading. Volume residuals versus unadjusted inventory age.

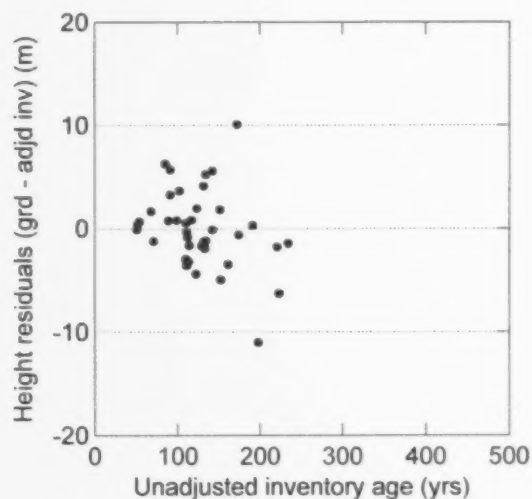


Fig. 27: Pl, Pa leading. Height residuals versus unadjusted inventory age.

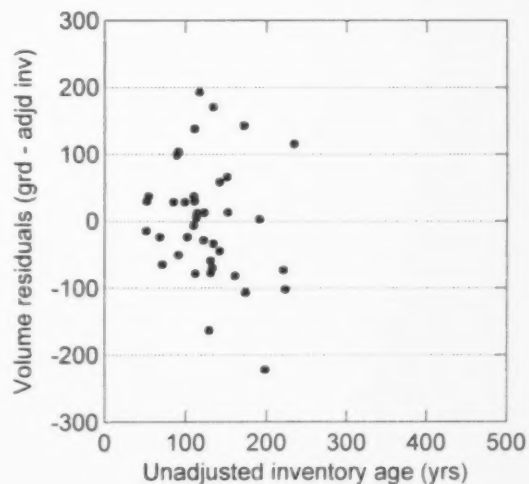


Fig. 28: Pl, Pa leading. Volume residuals versus unadjusted inventory age.

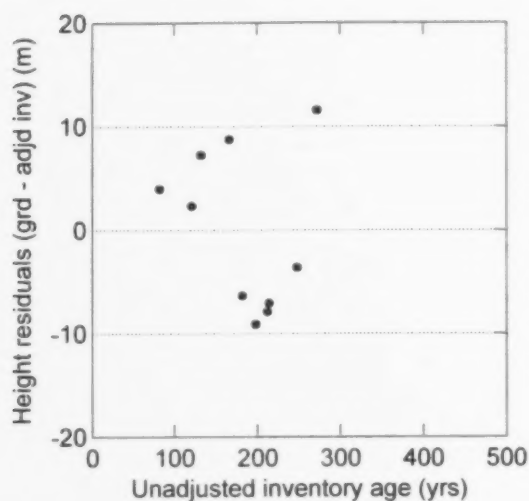


Fig. 29: Dry belt fir. Height residuals versus unadjusted inventory age.

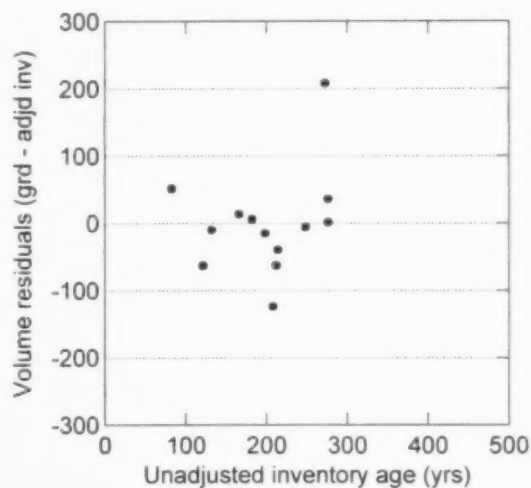


Fig. 30: Dry belt fir. Volume residuals versus unadjusted inventory age.

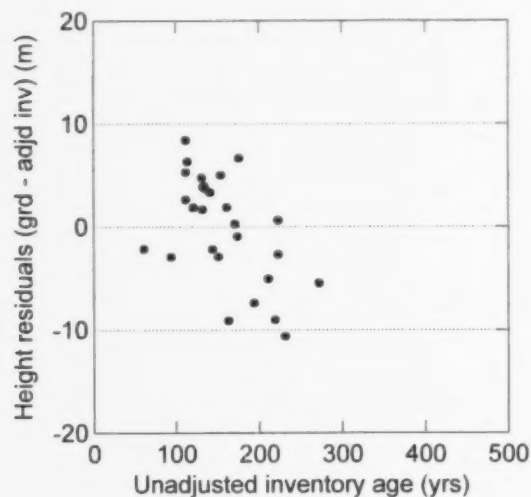


Fig. 31: Wet belt fir. Height residuals versus unadjusted inventory age.

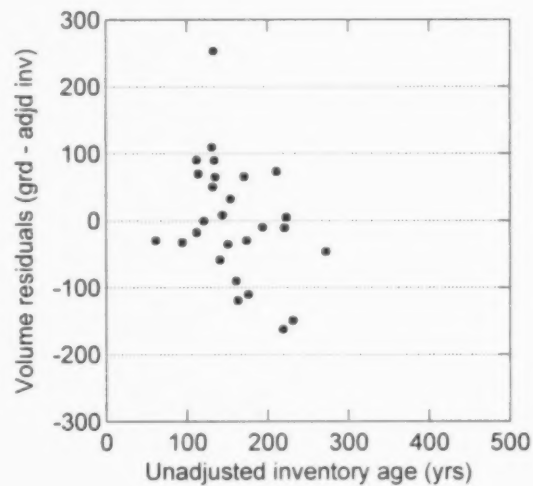


Fig. 32: Wet belt fir. Volume residuals versus unadjusted inventory age.

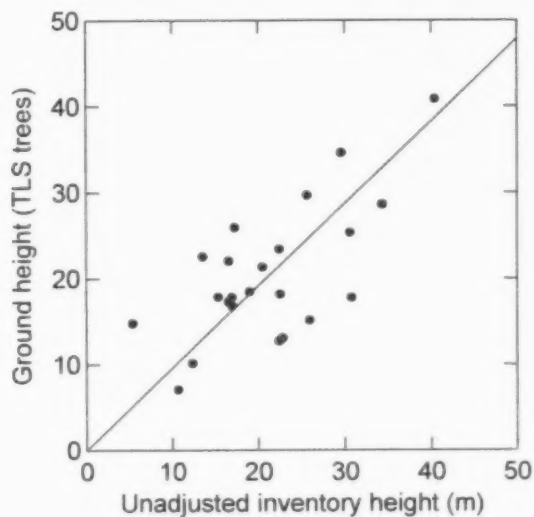
Age and height relationships: non-THLB, >30 years

Fig. 33: SB, Dec leading, non-THLB. Ground and inventory height relationship. Line corresponds to ratio of means.

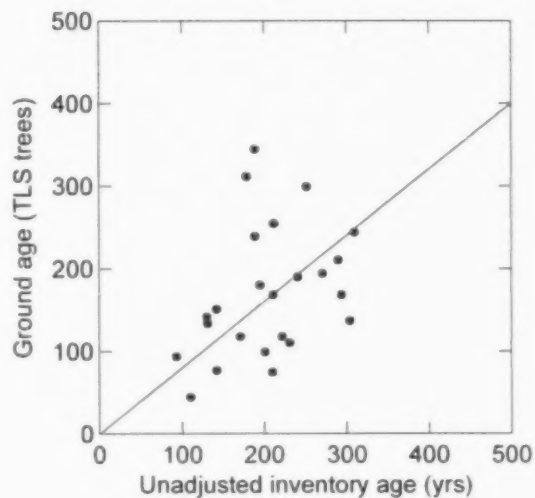


Fig. 34: SB, Dec leading, non-THLB. Ground and inventory age relationship. Line corresponds to ratio of means.

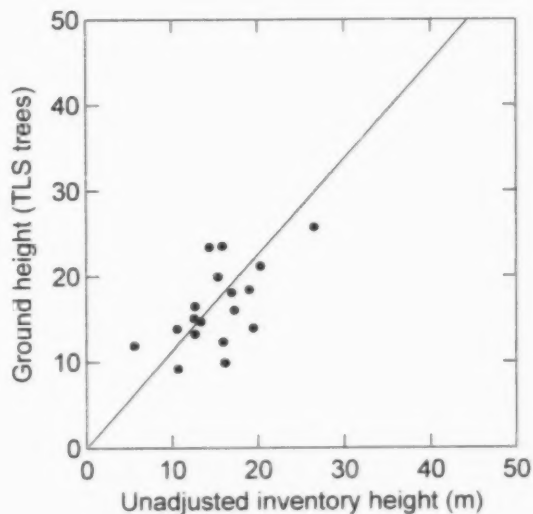


Fig. 35: Pl, Pa leading, non-THLB. Ground and inventory height relationship. Line corresponds to ratio of means.

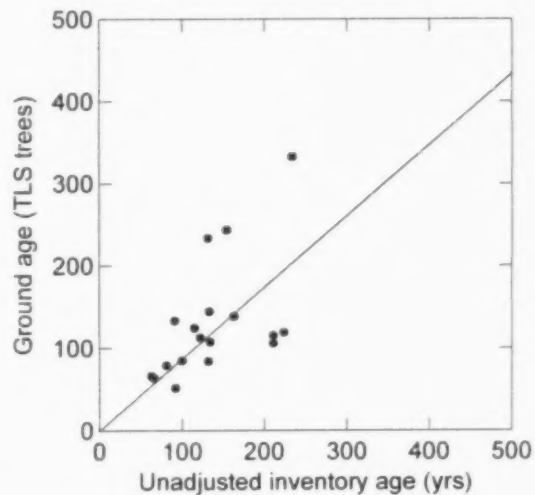


Fig. 36: Pl, Pa leading, non-THLB. Ground and inventory height relationship. Line corresponds to ratio of mean.

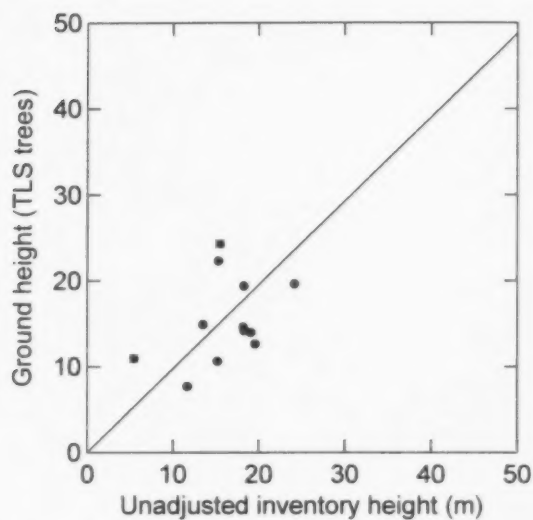


Fig. 37: Dry belt fir, non-THLB. Ground and inventory height relationship. Line corresponds to ratio of means.

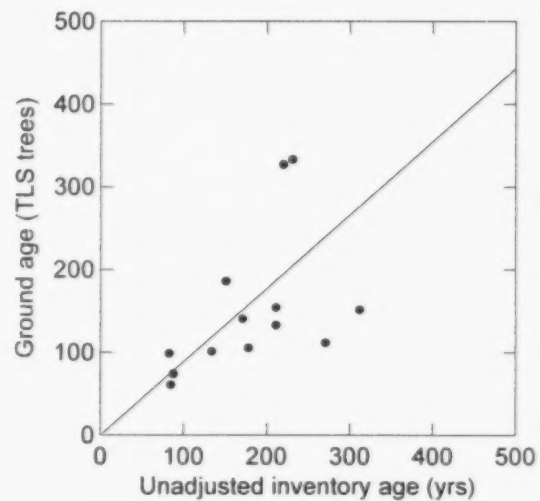


Fig. 38: Dry belt fir, non-THLB. Ground and inventory age relationship. Line corresponds to ratio of means.

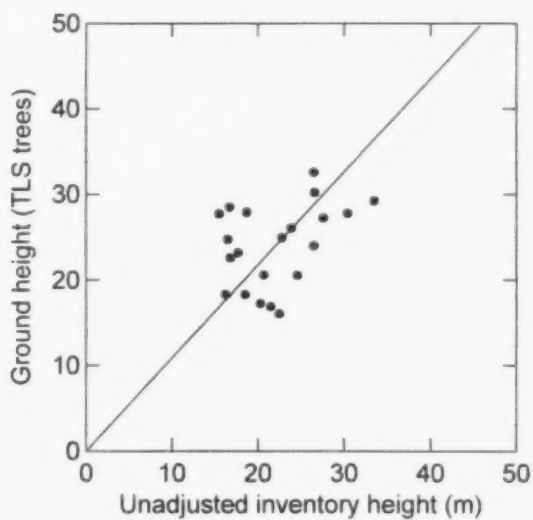


Fig. 39: Wet belt fir, non-THLB. Ground and inventory height relationship. Line corresponds to ratio of means.

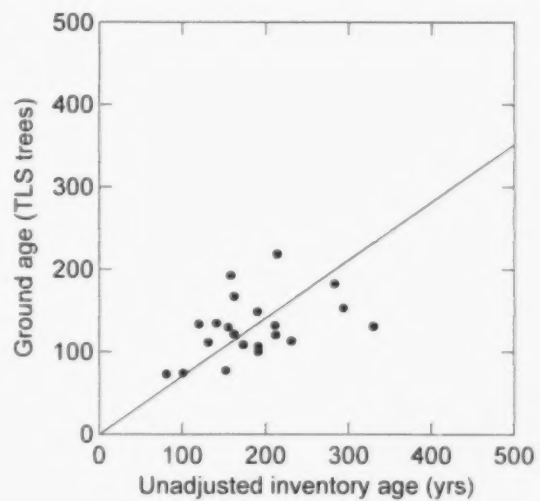


Fig. 40: Wet belt fir, non-THLB. Ground and inventory age relationship. Line corresponds to ratio of means.

Age and height residuals: non-THLB, >30 years

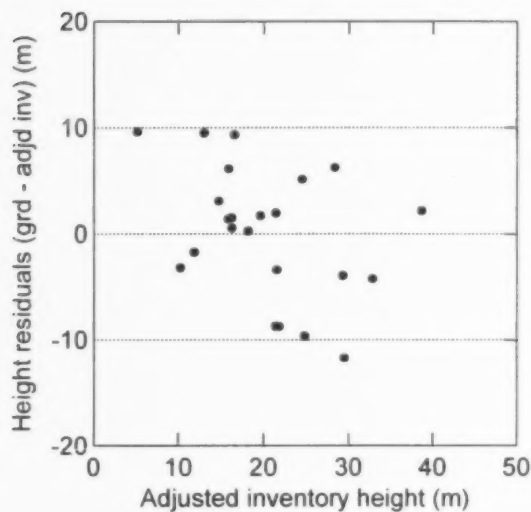


Fig. 41: SB, Dec leading, non-THLB. Height residuals vs adjusted inventory height.

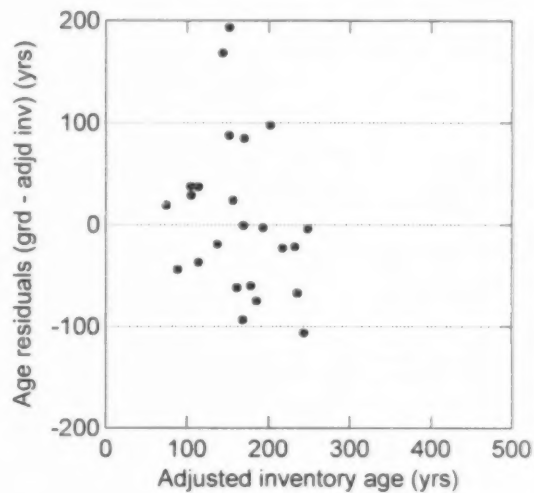


Fig. 42: SB, Dec leading, non-THLB. Age residuals vs adjusted inventory age.

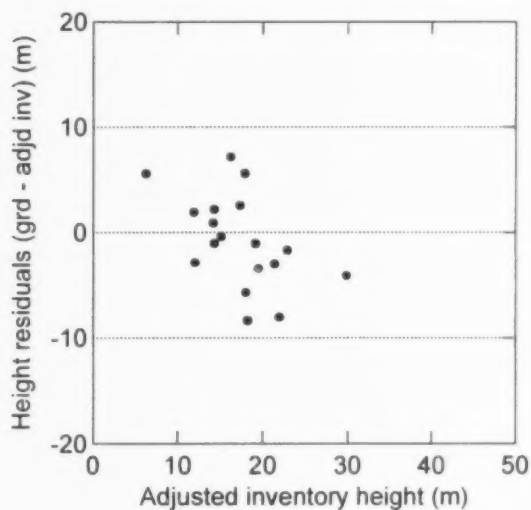


Fig. 43: Pl, Pa leading, non-THLB. Height residuals vs adjusted inventory height.

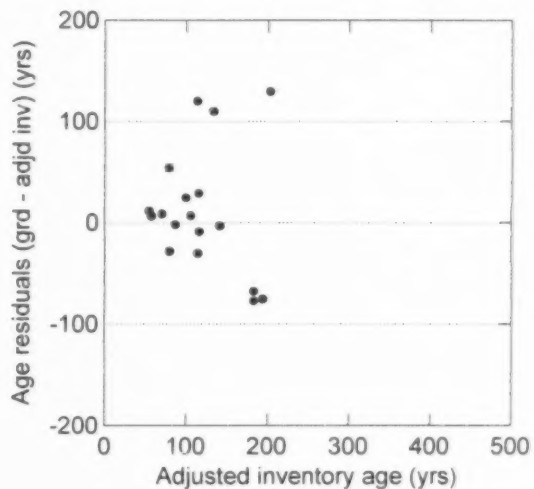


Fig. 44: Pl, Pa leading, non-THLB. Age residuals vs adjusted inventory age.

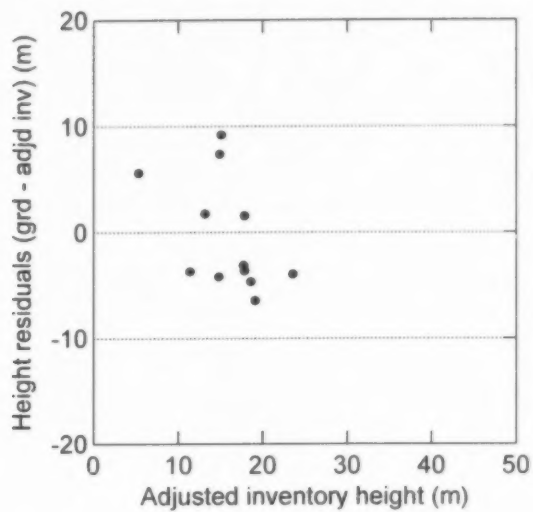


Fig. 45: Dry belt fir, non-THLB. Height residuals vs adjusted inventory height.

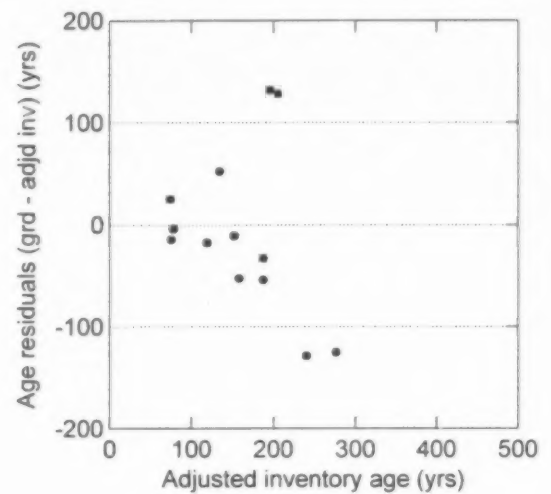


Fig. 46: Dry belt fir, non-THLB. Age residuals vs adjusted inventory age.

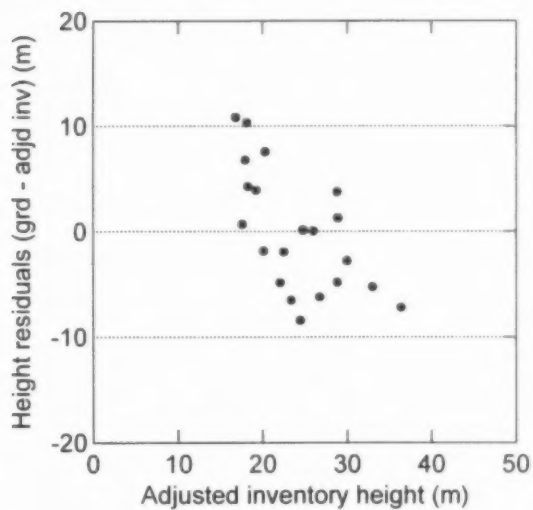


Fig. 47: Wet belt fir, non-THLB. Height residuals vs adjusted inventory height.

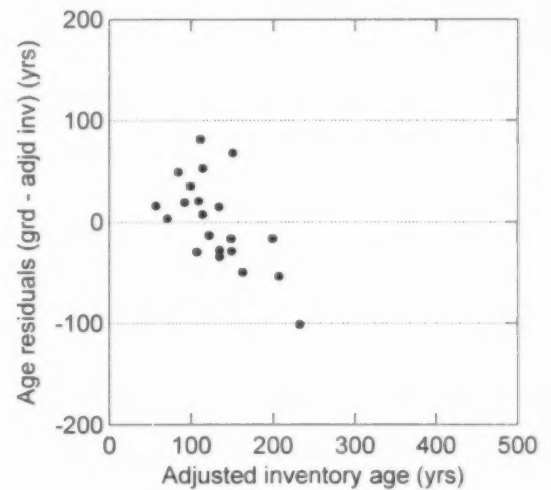


Fig. 48: Wet belt fir, non-THLB. Age residuals vs adjusted inventory age.

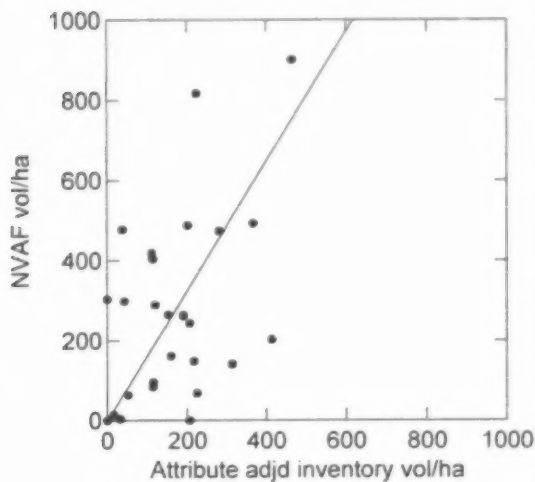
Volume relationships and residuals: non-THLB, >30 years

Fig. 49: SB, Dec leading, non-THLB. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

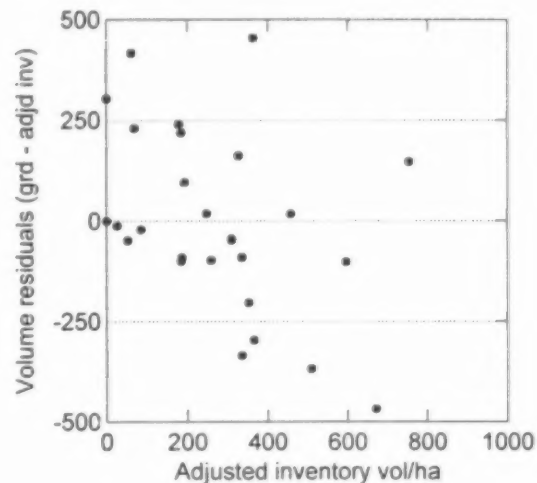


Fig. 50: SB, Dec leading, non-THLB. Volume residuals vs adjusted inventory volume.

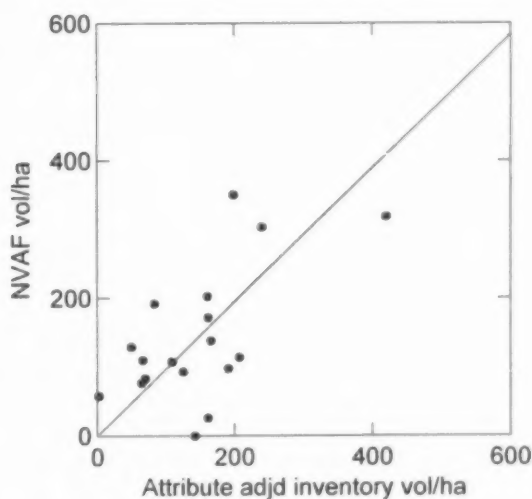


Fig. 51: Pl, Pa leading, non-THLB. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

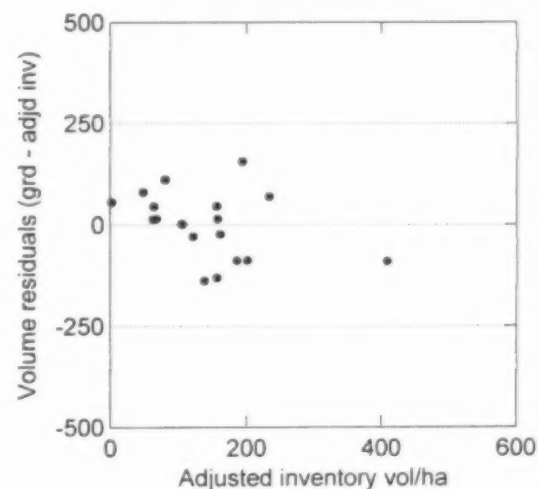


Fig. 52: Pl, Pa leading, non-THLB. Volume residuals vs adjusted inventory volume.

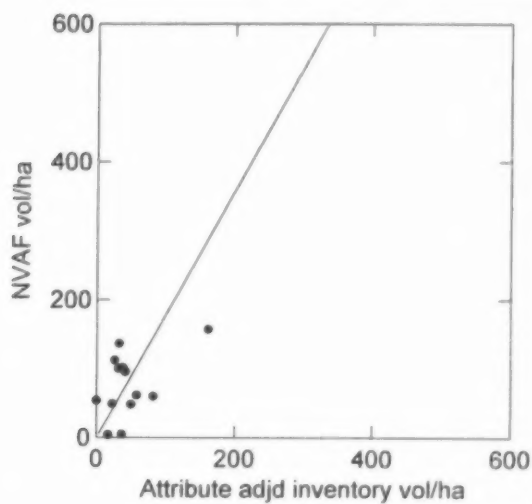


Fig. 53: Dry belt fir, non-THLB. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

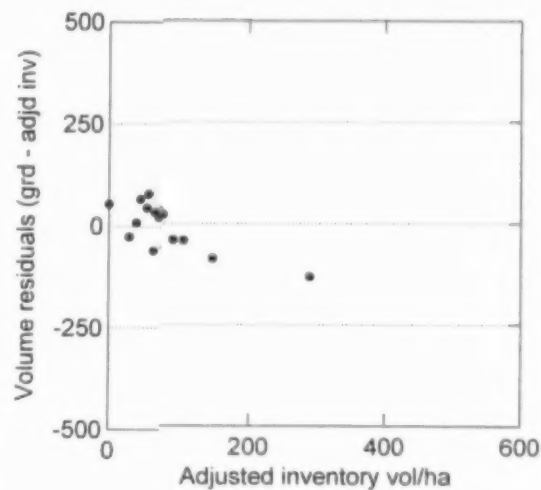


Fig. 54: Dry belt fir, non-THLB. Volume residuals vs adjusted inventory volume.

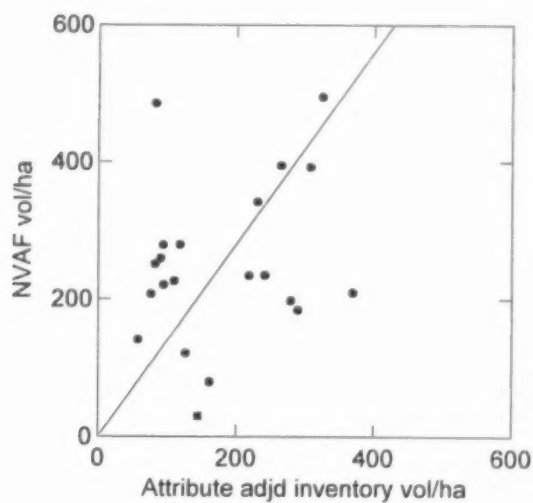


Fig. 55: Wet belt fir, non-THLB. Ground and attribute-adjusted inventory vol/ha relationship. Line is ratio of means.

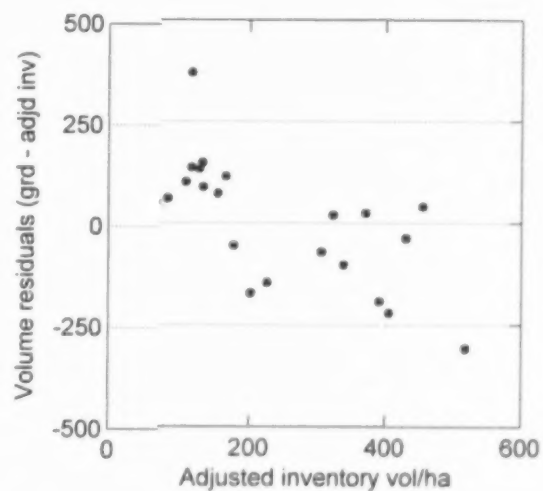


Fig. 56: Wet belt fir, non-THLB. Volume residuals vs adjusted inventory volume.

Height and volume residuals vs. inventory age: non-THLB, >30 years

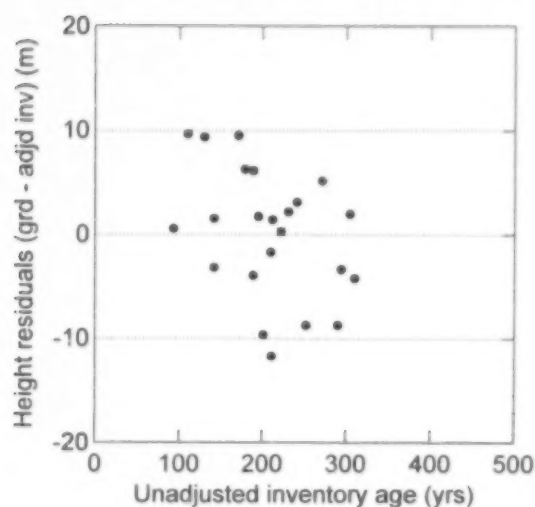


Fig. 57: SB, Dec leading, non-THLB. Height residuals versus unadjusted inventory age.

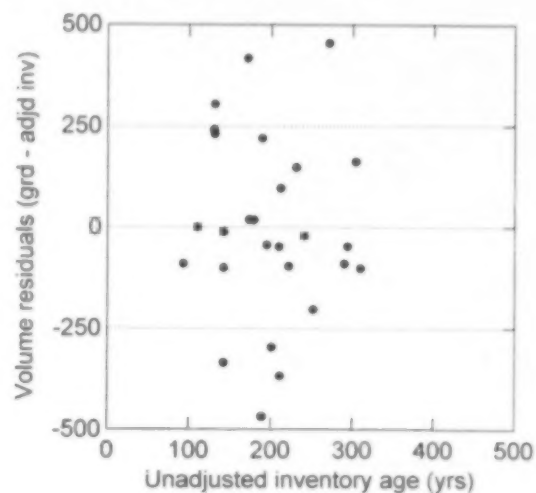


Fig. 58: SB, Dec leading, non-THLB. Volume residuals versus unadjusted inventory age.

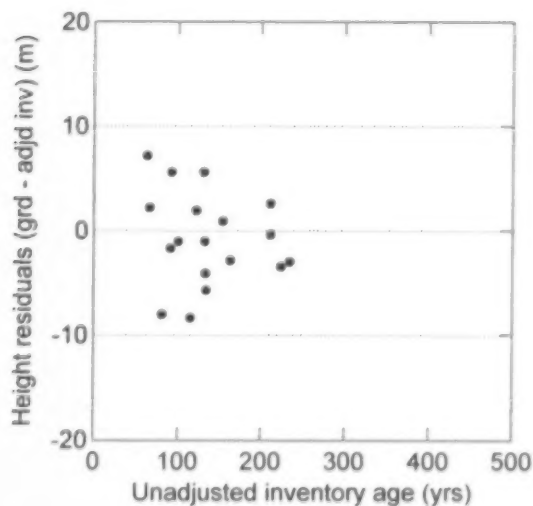


Fig. 59: Pl, Pa leading, non-THLB. Height residuals versus unadjusted inventory age.

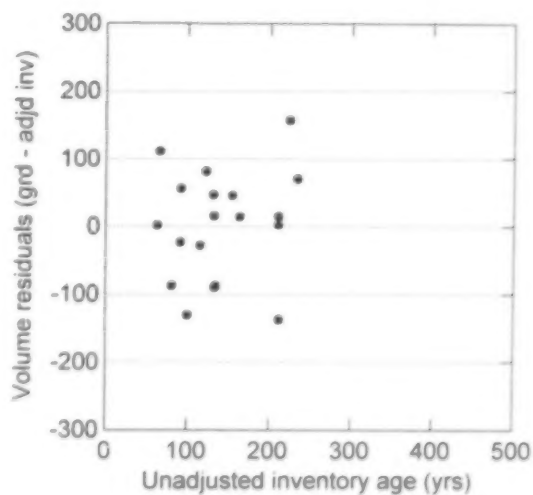


Fig. 60: Pl, Pa leading, non-THLB. Volume residuals versus unadjusted inventory age.

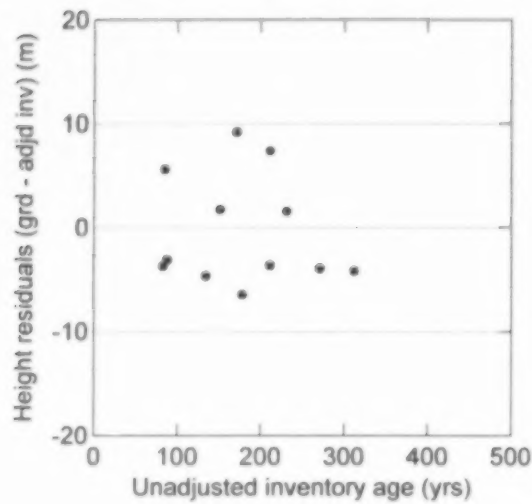


Fig. 61: Dry belt fir, non-THLB. Height residuals versus unadjusted inventory age.

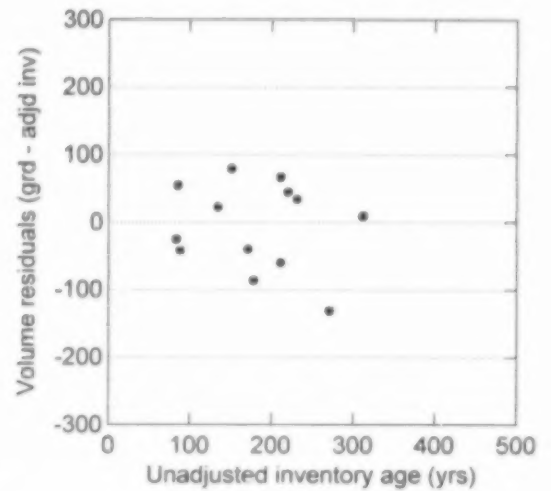


Fig. 62: Dry belt fir, non-THLB. Volume residuals versus unadjusted inventory age.

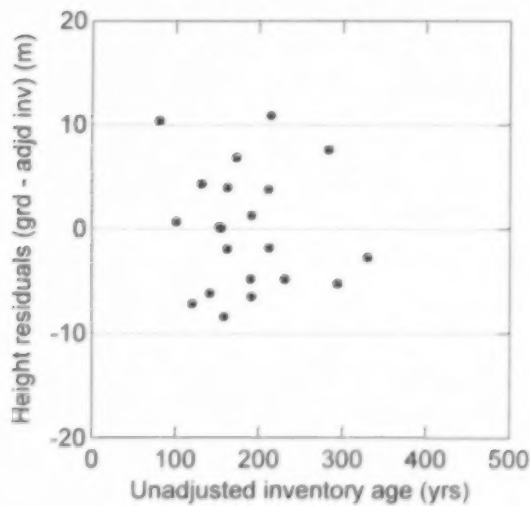


Fig. 63: Wet belt fir, non-THLB. Height residuals versus unadjusted inventory age.

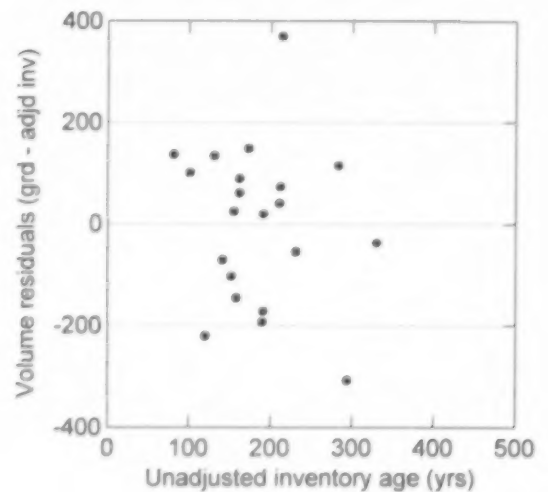


Fig. 64: Wet belt fir, non-THLB. Volume residuals versus unadjusted inventory age.

